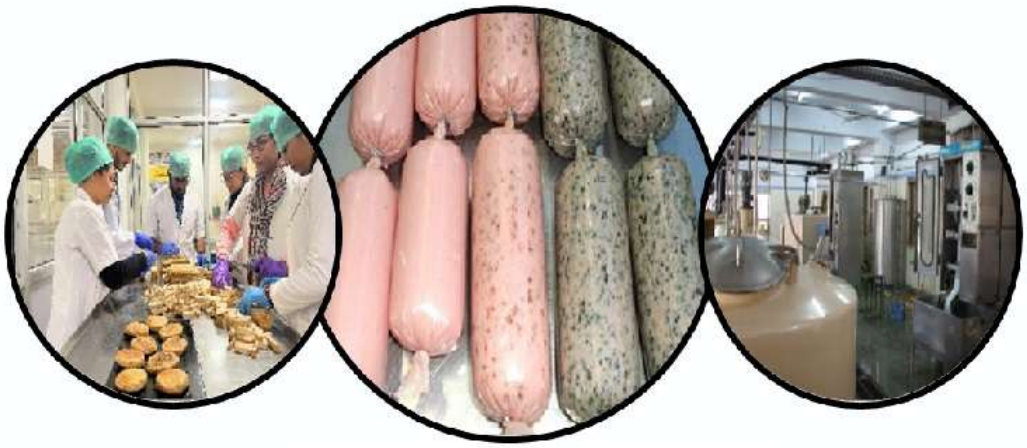
e-Book

Livelihood Improvement Through Value Addition of Animal Source Foods



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This e-book is a compilation of resource text obtained from various subject experts of ICAR-Indian Veterinary Research Institute, Izatnagar, Bareilly (IVRI) & MANAGE, Hyderabad, on "Livelihood improvement through value addition of animal source **f**oods ". This e-book is designed to educate extension workers, students, research scholars, progressive farmers, and academicians about Livelihood improvement through value addition of animal source **f**oods. Neither the publisher nor the contributors, authors, and editors assume any liability forany damage or injury to persons or property from any use of methods, instructions, orideas contained in the e-book. No part of this publication may be reproduced or transmitted without prior permission of the publisher/editors/authors. Publisher and editors do not give a warranty for any error or omissions regarding the materials in this book.

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निदेशक एवं कुलपति
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Director-cum-Vice Chancellor

FOREWORD

Livestock play a crucial role in the food supply by transforming low-value materials that are inedible or unpalatable to humans into valuable products like milk, meat, and eggs and provides approximately 13% of the energy and 28% of the protein consumed globally. Animal-sourced foods are essential for the healthy physical and cognitive development of infants, children, and adolescents, and also support the maintenance of physical function as we age.

The ICAR-Indian Veterinary Research Institute in Izatnagar, Bareilly (UP), is a globally recognized institution for research and education in Veterinary Science and Animal Husbandry. Established in 1975, the Division of Livestock Products Technology has become a key contributor to the development of various technologies focused on product innovation, ensuring optimal quality, safety, and extended shelf life, while also providing health benefits to consumers. The country is currently experiencing a positive transformation, progressing at all the fronts including food sector. Further, it's the need of the time that stakeholders and researchers collaborate at various levels to foster development at the grassroots level. To support this, the LPT Division regularly organizes training and extension activities for students, academicians, researchers, startups, entrepreneurs, farmers, and other stakeholders. In continuation of this, a five-day online training program titled "**Livelihood Improvement through Value Addition of Animal Source Foods**" will be organized jointly by the Division of Livestock Products Technology, ICAR-IVRI, Izatnagar, and MANAGE, Hyderabad, from September 10-14, 2024.

The scientists of LPT Division has compiled a resource e-book for this training programme and I appreciate their efforts for bringing out this publication. It is my firm belief that this e-book will be valuable not only to the trainees but also to other stakeholders involved in the value addition of animal-sourced foods.

(Triveni Dutt)

PREFACE

The e-book entitled "**Livelihood Improvement through Value Addition of Animal Source Foods"** embodies a transformative vision for improving rural livelihoods, enhancing food security and economic growth. However, challenges in productivity, quality, and market access hinder the full potential of this sector. Recognizing the importance and full potential of livestock sector to uplift rural communities, this comprehensive guide distils expert knowledge into practical strategies for enhancing productivity, quality, and marketability of animal source foods. Through value addition techniques, business acumen, and market insights, this e-book empowers livestock farmers, processors, and entrepreneurs to overcome challenges, capitalize on opportunities, and forge sustainable livelihoods. Covering value chain analysis, market trends, regulatory frameworks, and sustainable agriculture practices, this e-book further fosters innovation, collaboration, and knowledge sharing to support rural development and food security goals, ultimately unlocking the livestock sector's full potential.

We are grateful to EAASCentre, MANAGE, Hyderabad, ICAR-Indian Veterinary Research Institute, Izatnagar, Bareilly for their tireless efforts in compiling this e-book. We are also thankful to the authors, editors, and designers who have contributed to this book. We are hopeful and confident that this compiled document will be very much useful to the extension specialists, field workers, researchers, policy makers, food safety risk assessors and other stakeholders those who are involved in animal food business in align departments.

Editors

A. K. Biswas
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Chapter-1

Current status and future prospect of animal food processing sector in India

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1. Introduction

India is among the world's largest livestock-based economies, with a its diverse livestock population contributing around 4.1% to the national GDP and nearly 25% to the agricultural GDP. The dairy sector, which ranks first globally, accounts for over 22% of world milk production and supports rural livelihoods, particularly for small farmers and women. The processed dairy, meat, and egg industry in India is a growing sector that plays a crucial role in the nation's agricultural economy. This industry covers a broad range of value-added products, such as cheese, butter, yogurt, ice cream, sausages, cold cuts, chicken nuggets, and various ready-to-eat and ready-to-cook options. As the world's largest producer of milk, India is leading in the processed dairy segment as well, driven by rising urbanization, changing dietary patterns, and increasing consumer preference for convenience and quality.

Similarly, the processed meat industry is gradually developing, propelled by increasing demand for protein-rich foods and the growing popularity of convenience products. While buffalo meat dominates the export market, there is also a growing domestic requirement for processed poultry and mutton products. However, the industry faces challenges such as limited cold chain infrastructure, high costs of imported processing equipment, and the need for adherence to stringent safety and quality standards.

The processed egg industry, though smaller in scale, is also growing steadily with increasing demand for liquid eggs, egg powders, and value-added products like egg-based snacks and fortified foods. Modern retail outlets, improved packaging, and enhanced cold chain facilities lead to the growth of these segments.

Overall, the processed dairy, meat, and egg industry in India is set for augmentation, supported by technological advancements, government initiatives, and ever-evolving consumer needs. The processed food sector pertaining to animal foods is a wing of livestock based economy that has a lot to offer and still operating at a very shy pace.

2. Current Animal Resources in India

As per the 20th Livestock Census, India’s livestock population has reached 535.78 million, with a slight increase of 4.63% compared to the previous census. Cattle

constitute 192.49 million of the population, reflecting a growth of 0.83%. Buffaloes number 109.85 million, with a 1.06% increase. The sheep and goat populations have seen significant growth of 14.13% and 10.14%, reaching 74.26 million and 148.88 million, respectively. The pig population in India is approximately 9.06 million. This represents a slight decline of about 12.03% compared to the previous census. The total poultry population has grown by 16.81% to 851.81 million, with notable increases in backyard poultry (45.78%) and commercial poultry (4.5%).

As per NBGAR, there number of registered breeds for different species are: 53 breeds for cattle, 20 for buffalo, 39 for goat, 45 for sheep, 8 for horses & ponies, 9 for camel, 14 for pig, 3 for donkey, 3 for dog, 1 for yak, 20 for chicken, 3 for duck, and 1 for geese. India's vast animal resources provide a strong foundation for the advancement of the animal-based food processing sector. This immense livestock wealth serves as the backbone of the entire processed food industry in the country, offering significant potential for expansion and development.

3. Overview of Animal Based Processing Industry

India has achieved significant progress in strengthening its livestock product-based economy, reflecting substantial growth in sectors such as meat, poultry, dairy, and wool. Meat production has risen from 6.69 million tonnes in 2014-15 to 9.77 million tonnes in 2022-23, marking a significant growth rate of 5.13% in the latest year and boosting per capita meat availability to 7.10 kg annually. As of August 2024, there are 91 slaughterhouses in India that are registered and approved by the Agricultural and Processed Food Products Export Development Authority (APEDA). These include 73 integrated abattoirs that also function as meat processing plants, 11 standalone meat processing plants, and 7 standalone abattoirs.

The poultry sector has undergone a transformation from traditional farming to a more modern, commercial production system, aided by state-of-the-art technologies. As a result, the poultry population reached 851.81 million, with egg production hitting 138.38 billion in 2022-23, and per capita availability rose to 101 eggs per annum, demonstrating a growth rate of 6.77%.

India has upheld its position as the largest milk producer across the globe, owing to governmental initiatives aimed at enhancing livestock productivity. Milk production rose from 222.07 million tonnes in 2021-22 to 230.58 million tonnes in 2022-23, achieving growth at an annual rate of 3.83%, with per head per day milk availability at 459 grams per day. Under the Dairy Processing and Infrastructure Development Fund (DIDF), as of September 2023, India established a milk processing capacity of 69.95 lakh litres per day (LLPD), a chilling capacity of 3.40 LLPD, and a drying capacity of 265 metric tonnes per day (MTPD). Although wool production has faced some challenges, dropping to 33.61 million kg in 2022-23 from 48.14 million kg in 2014-15, strategic efforts have been tried to maintain a modest growth rate of 2.12%.

These developments underscore India's commitment to modernizing its livestock industry, improving animal husbandry practices, and enhancing productivity, which have collectively strengthened the country’s livestock product-

based economy and contributed to rural livelihoods, nutrition security, and economic growth.

4. Export Potential of Various Livestock Products

The annual animal products export from India, in 2023-24 was Rs. 37,665.51 crores. Out of the total, export in buffalo meat was Rs. 31010.10 crores, sheep/ goat meat was Rs. 643.55 Crores and other Meats were Rs. 6.82Crores. The exports in poultry products and dairy products were to the tune of Rs. 1530.20 crores and Rs. 2260.94 crores respectively. Byproducts like animal casing and albumin earned around Rs. 399.21crores and Rs. 150.24 crores, respectively. Furthermore, processed meats and albumin (egg & milk) were traded in for Rs. 20.55 Crores and Rs. 173.06 crores, respectively.

The rising global demand for Indian buffalo meat has led to a notable surge in meat exports. In the fiscal year 2023-24, buffalo meat accounted for more than 82% of India's total animal product exports. Key markets for Indian buffalo meat and other animal products include Malaysia, Vietnam, Egypt, Indonesia, and the United Arab Emirates.

5. Current Trends and Market Dynamics

India's meat processing segment has a total capacity exceeding 1 million tons per annum, with only 40-50% of this capacity currently utilized. In the fiscal year 2023-24, India exported approximately 2,773,498.74 tonnes of animal products, primarily buffalo meat, which is in high demand internationally because of its low fat (lean) and nearly organic nature. The meat processing segment in India focuses on creating value-added, diverse, and convenient products to meet changing consumer lifestyles. For example, to efficiently use tougher meat from spent buffalo, products are developed by mincing the meat and incorporating other ingredients to enhance quality and taste.

Key regions for production of processed meat in our nation include Andhra Pradesh, West Bengal, Maharashtra, Kerala, Delhi, Uttar Pradesh, and Rajasthan. In 2023-24, India exported 813.72 tons of processed meat, valued at Rs. 20.55 Crores (USD 2.48 million), to various international markets. During this period, key destinations for Indian processed meat exports included Vietnam, Bhutan, Qatar, the United Arab Emirates, South Korea, and Hong Kong. These figures reflect the growing global presence and demand for Indian meat products.

Poultry is currently one of the fastest-growing segments within India's agricultural sector, fueled by rising per capita income, an expanding urban population, and decreasing poultry prices. In the 2022-23 period, India produced 138.38 billion eggs, ranking third globally in total egg production. This reflects a 6.77% increase than the preceding year, with a per individual availability of 101 eggs per annum. The advancement of the poultry industry is being driven by growing incomes, a rapidly expanding middle class, and the rise of vertically integrated poultry companies that have managed to cut consumer prices by minimizing production and

marketing expenses. The shift from fresh meat to frozen and convenience products, coupled with policies that guarantee competitively priced supplies of corn and soybeans, is key to the industry's future expansion in the country.

The country's top five egg-producing states—Andhra Pradesh, Tamil Nadu, Telangana, West Bengal, and Karnataka—account for nearly 65% of total production. Out of the total egg production, 118.16 billion eggs come from commercial poultry (85.4%), while backyard poultry contributes 20.20 billion eggs (14.6%). India also hosts numerous small poultry processing plants that produce dressed chickens and manufacture egg powder and frozen egg yolk for export. In 2023-24, India exported 1,275,234.90 metric tons of poultry products, valued at Rs. 1,530.20 crores (USD 184.58 million), with key export sites including Oman, Indonesia, Maldives, Qatar, the United Arab Emirates, and Sri Lanka.

As the second-most populous country globally, India has diverse cultural, religious, and socioeconomic factors that strongly influence meat consumption patterns. As of 2022-23, India's per capita meat consumption stands at around 7.10 kg per year, a modest figure compared to the global average of approximately34 kg per year. This difference reflects the country's diverse dietary practices, cultural norms, and economic factors, which contribute to a predominantly vegetarian diet Within a substantial portion of the population. However, meat consumption in India is increasing, fueled by swift urbanization, evolving lifestyles, and growing incomes and growing awareness of the nutritional benefits of animal protein.

6. Technological Advancements in Animal Food processing

Recent technological advancements in India's meat processing sector have focused on improving meat quality, shelf life, safety, and sensory attributes. There is significant interest in using natural antioxidants and antimicrobials derived from plants, herbs, and agro-waste to increase the shelf life and safety of animal-based foods. Methods have been established to enhance meat tenderness, especially for buffalo meat, by employing plant-based proteases such as *Cucumis trigonus* roxb, ginger and papain, as well as chemicals likes ammonium hydroxide. Researchers have also employed proteomics to examine meat color and oxidation caused by lipids, providing insights into preserving freshness. To enhance storage stability, antioxidants like sodium ascorbate and rosemary phenols have been effectively used in ground buffalo meat. Techniques such as high-pressure processing (HPP), cold plasma treatment, and pulsed electric fields (PEF) are being explored to inactivate pathogens and reduce spoilage without compromising flavor, texture, or nutritional content. These methods offer alternatives to conventional chemical preservatives, meeting consumer demand for cleaner, more natural products.

Innovative packaging solutions, such as on-package indicator sensors, have been created to monitor freshness by detecting volatile nitrogen compounds released during storage. The adoption of automation, robotics, and digital technologies is a growing area of research aimed at improving efficiency, consistency, and traceability in animal food processing. Algorithms for machine learning and artificial intelligence

(AI), and blockchain technology are being applied to enhance production processes, forecast equipment maintenance requirements, oversee quality, and guarantee transparency in the supply chain. Robotics and automation are also being incorporated into meat processing lines to reduce labor costs, enhance safety, and improve precision in tasks like deboning, cutting, and packaging.

In response to the frequent adulteration of meat, molecular techniques like polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP) have been employed for species identification and traceability. However, despite a meat processing capacity of over 2 million tonnes per year, only a small percentage of this capacity is utilized for value-added products, largely due to the high cost of imported processing machinery and limited local manufacturing options. The market is being propelled by a growing demand for processed and ready-to-eat meat products, resulting in the expansion of modern retail outlets with enhanced packaging, labeling, chilling, and cold-chain capabilities.

R&D efforts have focused on creating functional and enriched meat products from culled animals and poultry, such as sausages, meat loaves, burger patties, and restructured meat nuggets. Methods have also been created for the production of sous-vide chicken sausages, pork nuggets with fermented bamboo shoots, and mutton nuggets incorporated with grape seed extract. These advancements highlight the growing diversification and advancement of the Indian meat processing industry, which is poised to expand further with continued innovation and market growth.

7. **Regulatory Framework and Quality Standards**

The regulatory framework and quality standards governing the Indian livestock product industry, including milk, meat, and eggs, are established to ensure safety, hygiene, and quality for domestic consumption and export. The Food Safety and Standards Authority of India (FSSAI) set comprehensive regulations under the Food Safety and Standards Act, 2006, which includes standards for dairy products, meat and meat products, and egg products. These standards cover permissible limits for contaminants, microbiological safety, additives, and labeling requirements. The Bureau of Indian Standards (BIS) provides voluntary, specific guidelines and the "AGMARK" certification for quality assurance. For meat and meat products, the Export Inspection Council (EIC) and the Agricultural and Processed Food Products Export Development Authority (APEDA) enforce standards to meet international export requirements, including ante-mortem and post-mortem inspection, hygiene practices in abattoirs, and the processing and packaging of meat. The poultry and egg industry is regulated under standards set by the National Egg Coordination Committee (NECC) and the Animal Husbandry and Veterinary Department at state levels. These standards emphasize hygiene, biosecurity, and safe handling practices to prevent contamination and disease outbreaks. The regulatory framework aims to maintain consumer safety, facilitate exports, and improve the overall quality and competitiveness of the Indian livestock product industry. Continuous monitoring, updates to standards, and enforcement through licensing, inspections, and

certifications are critical aspects of this framework. The regulatory framework established by FSSAI and other bodies ensures that animal food products in India meet stringent safety and quality standards, protecting both consumers and the industry. Regular updates and enforcement of these standards are essential for preserving public trust and health.

8. Challenges faced by the animal food processing sector

The animal food processing sector in India faces several significant challenges that impede its growth and development. One of the primary issues is the deficiency in infrastructure, particularly in cold storage facilities and efficient transportation networks, which leads to substantial post-production losses, especially for perishable products like meat, dairy, and fish. Additionally, the sector lacks modern processing units equipped with advanced technologies, resulting in inefficiencies and lower productivity. Regulatory hurdles further complicate matters, with businesses often struggling to navigate complex regulations and comply with stringent food safety norms.

Supply chain issues are also prevalent, with a fragmented and unorganized supply chain leading to inefficiencies, higher costs, and challenges in ensuring the traceability and quality of raw materials. Moreover, the sector suffers from a shortage of skilled labor, particularly in specialized areas such as meat processing and quality control. The limited availability of training institutes and high attrition rates further exacerbate this issue, affecting the overall productivity of the sector.

Quality and safety concerns are another major challenge, with inconsistent quality across the sector, particularly among unorganized players. Ensuring compliance with international food safety standards is difficult, especially for exporters, due to gaps in quality control and monitoring mechanisms. Market access and export challenges also persist, with many small and medium enterprises (SMEs) struggling to access domestic and international markets due to inadequate branding, marketing strategies, and knowledge of export requirements. Trade barriers, including non-tariff barriers in export markets, further hinder the sector's growth.

Environmental and ethical issues are gaining prominence, with concerns about the environmental impact of animal farming and processing, such as waste management, water usage, and greenhouse gas emissions. The sector faces increasing pressure to adopt more sustainable and humane practices, which often involve significant operational changes and increased costs. Technological adoption is another area where the sector lags, with slow uptake of modern technologies like automation, artificial intelligence, and blockchain for traceability, limiting efficiency, transparency, and the ability to meet global standards. The high cost of technological upgrades and the lack of financial support or incentives for smaller players further hinder progress in this area.

Lastly, changing consumer preferences and a lack of awareness about the nutritional value of processed animal products pose additional challenges. The sector needs to adapt to the growing demand for healthier, organic, and ethically produced

food. Addressing these challenges requires coordinated efforts from the government, industry stakeholders, and policymakers to create a more conducive environment for the growth and modernization of the animal food processing sector in India.

9. Opportunities for growth and development

The growth potential in India's meat processing industry is substantial, particularly given the rising demand for clean, safe, and hygienic meat products. Key opportunities include the modernization of municipal abattoirs and the establishment of large-scale abattoirs-cum-meat processing plants utilizing advanced technologies. Investments in cold chain infrastructure, such as cold storage at points of sale, logistics, and processing facilities, are expanding to accommodate shifting consumer preferences.

Proactive government policies, like the Mega Food Park Scheme, provide robust infrastructure support for the food processing sector, with plans for 42 mega food parks to enhance the industry's capabilities. Additionally, the sector presents opportunities for technology and equipment suppliers in areas like modern meat and poultry processing technologies, abattoirs, cold chains, and veterinary services. There is considerable potential for developing value-added products, such as frozen and chilled items, ready-to-cook (RTC) and ready-to-eat (RTE) foods, Indian ethnic snacks, and egg powder. Fiscal benefits further boost investment appeal, with incentives including 100% income tax exemption for the first five years for new food processing units, a 150% income tax deduction on capital expenditure for setting up cold chains or storage facilities, and affordable credit options facilitated by a ₹20 billion fund through the National Bank for Agriculture and Rural Development (NABARD).

Overall, India's meat and poultry sector is well-positioned for growth, driven by a large and diverse livestock base, increasing domestic and international demand, supportive government policies, and substantial investment in infrastructure and technology. These factors combine to make India an attractive destination for investors and stakeholders in the global meat processing industry, with significant potential for value addition, export growth, and technological innovation.

10. **Future prospects and strategic roadmap**

The future prospects of the animal food processing sector in India are highly promising, driven by a combination of growing domestic demand, increasing export potential, and government support for modernization and value addition. As the world's largest producer of buffalo meat and the second-largest producer of goat meat, India has a strong foundation to expand its footprint in the global meat market. The ongoing economic growth, urbanization, rising disposable incomes, and shifting consumer preferences towards clean, safe, and processed meat products provide a fertile ground for the sector's expansion. To capitalize on these opportunities, India must focus on a strategic roadmap that includes several key elements:

- Enhancing infrastructure and technological capabilities: This includes investing in state-of-the-art abattoirs, cold chain logistics, and advanced processing facilities

that meet international standards for hygiene and quality. The development of modern abattoirs and large-scale meat processing plants equipped with the latest technology can help improve efficiency, reduce wastage, and ensure food safety.

- Diversification of product offerings: The products that align with the global trend of convenience foods and can help tap into new consumer segments. Innovation in product development, such as incorporating functional ingredients or creating fortified meat products, can further enhance market appeal and meet the rising demand for health-conscious options.
- Fostering stronger market linkages and export-oriented growth: India should aim to expand its presence in existing markets like Vietnam, Malaysia, Egypt, Thailand, and Saudi Arabia while exploring new markets in Europe, North America, and other parts of Asia. Promoting Indian meat and poultry products through international trade fairs, marketing campaigns, and diplomatic efforts can help strengthen the country's image as a reliable supplier of high-quality meat products.
- Capacity building and skill development: Investments in training programs for workers in the meat and poultry processing industries, focusing on hygiene practices, advanced processing techniques, and quality control, can enhance productivity and ensure adherence to global standards. Establishing research and development (R&D) centers focused on innovative processing methods, product development, and waste utilization can further drive growth and sustainability in the sector.
- Strengthening the regulatory framework and food safety standards: Implementing stringent quality control measures, traceability systems, and certification standards will help align Indian products with international expectations, thereby enhancing their competitiveness in global markets. Government initiatives like the Mega Food Park Scheme and the Scheme for Cold Chain, Value Addition, and Preservation Infrastructure provide a strong foundation for infrastructure development, and these should be further scaled up to cover more regions and sectors.
- Sustainable practices and circular economy principles: Utilizing animal by-products, waste management through composting or biogas generation, and adopting eco-friendly packaging solutions can help reduce the environmental footprint of the meat processing industry.

In conclusion, the animal food processing sector in India holds significant potential for growth and diversification. By focusing on infrastructure development, product innovation, market expansion, skill enhancement, regulatory strengthening, and sustainability, India can strategically position itself as a global leader in the meat processing industry. This comprehensive approach will ensure that the sector not only meets the growing domestic demand but also captures a larger share of the international market, contributing to economic growth and rural development in the country.

****References can be requested from the authors****

Chapter-2

Value chain approach for production and processing of milk, meat and poultry products

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1. Introduction

India has a significant livestock population of 536.73 million and about 851.81 million poultry. As per the recent data, the Gross Value Added (GVA) of the livestock sector is about Rs 13,55,460 crores at current prices during FY 2022-23, which is about 30.23 % of Agricultural & Allied Sector GVA and 5.50 % of Total GVA with a positive annual growth of 5.02%. The meat and egg production during 2022–23 was 9.77 MT, and around 138.38 billion numbers with an annual growth of 5.13 and 6.77% respectively. India is the largest producer of milk in the world, with 230.58 MT contributing approximately 25% of global milk production. The current milk production scenario reflects the continuous growth driven by increased dairy farming and productivity improvements. The dairy sector alone contributes about 4.5–5% to India's GDP and is a critical source of income for millions of rural households.

The present system of production and marketing of milk and meat for domestic and export market is endowed with multifarious challenges and needs corrective measures at various levels. There are multiple stakeholders along the milk and meat value chain, but most of them operate in isolation and lack of information at various levels along the chain. The whole idea of a value chain is to generate value for all the actors while analyzing how the various actors in the chain exchange knowledge to enter the market (Sen et al., 2022). Growth and development of livestock value chains for local and external markets can be considered as a powerful tool for poverty reduction and to fight against the challenge of food-security in developing countries like India. There are number of stakeholders involved in the livestock commodity value chains and the partitioning of gains among the stake holders along the chain is often debated and analysed. Farmers, traders, wholesalers, retailers, big retail chains and consumers are major actors of the vale chain. There is very little processing in India, hardly 2% of the total meat produced except 10% in poultry and remaining meat are sold in fresh or frozen form. In India, value chain and stakeholders varies with the type of livestock products, their marketing and retailing pattern. The value chain for meat, milk, and poultry products is complex and can face challenges that impact efficiency, profitability, and sustainability.

2. What is Value Chain?

A value chain is a full range of activities that include designing, production, marketing and distribution of a product or service from conception to delivery. For companies that produce goods, the value chain starts with the raw materials that are used to make their products and consists of everything added before the product goes to consumers (Harrison, 2019). In contrast to a supply chain, value chain, on the other hand, is a set of activities that focuses on creating or adding value to the product. Its goal is to distinguish which activities are the most valuable to the firm and which ones could be improved to provide competitive advantage.

3. Livestock value chain

The livestock value chain can be defined as the full range of activities involving different people that are required to bring a product (e.g. live animal, meat, milk, egg, day old chick, feed, medicine, leather, fiber, manure) to final consumers passing through the different phases of production, processing and delivery. It can also be defined as a market-focused collaboration among different stakeholders who produce and market value-added products. Value chain analysis is essential to an understanding of markets, their relationships, the participation of different actors, and the critical constraints that limit the growth of livestock production and consequently the competitiveness of farmers.

4. Value chain of livestock products

The value chain for meat, milk, and poultry products is the range of activities that bring a product from the farm to the consumer. The value chain includes:

- Production: This includes breeding and hatching, feed production, health and animal rearing practices.
- Processing: This includes primary, secondary and further processing of value added products.
- Packaging and storage: This includes packaging and storage of the livestock products.
- Transport and distribution: This includes transporting and distributing the products to the retailers and consumers.
- Retail: This includes retailing the products to consumers.

5. Importance of value chain

The value chain in the meat and milk processing industry is important for several reasons, including sustainability and efficiency. The sustainability of the meat value chain is important for the environment, as well as for economic and social needs (FAO, 2014). Value chain analysis helps to understand the relationships between different actors in the market, and the constraints that limit the growth of livestock production. Value chain analysis can help to measure the efficiency of activities in the value chain. The value chain is one aspect of increasing productivity through improving quality, efficiency, and product differentiation. Corrective action in the value chain is carried out by identifying activities that provide business value,

determining positions, and eliminating activities that do not provide value to products or services.

6. Components of meat value chain

6.1. Availability and supply of breeding stock

Breeds mainly can be improved with two methods one is crossbreeding and the other up-grading. But there are many challenges in improving the breeds, like the availability of elite bull and lack of awareness among the farmers about the scientific breeding practices.

6.2. Feed Supply and nutritional availability

Poor nutrition is one of the major production constraints in smallholder systems. The feed and fodder resources play prominent role in profitable livestock farming as it constitutes the major share of rearing expenses. Food and feeds contribute almost 60-70 per cent of the overall recurring expenditure so that the profitability of the farm can be improved by economic feeding of livestock. The key issue is feed scarcity, low nutritional quality feeds and imbalance feeding. Feeding the balanced ration to dairy animals increases efficiency and thus reduces the cost of feeding (Singh et al., 2019).

6.3. Animal Health Care

The occurrence of diseases is an important factor which influences the productivity and economy of animal farming. Diseases in animals result in mortality and morbidity losses, resulting in low productivity of animals (Singh and Prasad, 2008). Advances in animal health are expected to play a major role in the progress of livestock industry. Control of animal diseases assumes prime importance in the crucial time of shifting of animal agriculture from extensive to intensive and commercial system of management.

6.4. Animal Transportation

The value chain of animal transportation for the domestic market is very informal. Traders play a very active role in this value chain as intermediary aggregators. Farmers (primary producers) have limited market access and are isolated from major consumers due to logistical and transport costs. Farmers often avoid these costs directly by selling to intermediary aggregators. Traders buy animals from various farmers and pool them for further marketing or haul purchased animals to municipal slaughterhouses.

6.5. Market Infrastructure

Production and marketing aspects of livestock produce are intertwined with each other. Market-driven production rather than production–propelled marketing is the order of the day. The market map is an analytical tool that helps in understanding policy issues. Like other agricultural markets in India, those for livestock have also remained underdeveloped, in fact, much less developed in comparison to crop based commodities.

6.6. Retail Meat shops

Meat sector activities including retailing of meat play a substantive role and bring great value by supporting local economies and enriching livestock farmers and other stakeholders across the value chain. According to industry research, the size of India's

meat market is close to $30-35 billion, which is further growing at around 18-20% every year (Business Line, 2019). In India, food retailing, is in focus since new retail chains are giving competition to small stores, as these do not sell meat.

6.7. Supermarkets & e-marketing

Indian retail is one of the fastest growing markets in the world and fifth largest global destination in the retail space. In the year 2006 India had 500 supermarkets which increased to 12000 at present. There is a huge opportunity for branded players and for the organized retail to grow and expand the market because people have until now preferred fresh meat. But now people are becoming aware of the hygiene and quality of fresh and semi processed meat and this segment is picking up and witnessing huge demand and hence there is a plenty of scope to expand the business of e-marketing of meat.

6.8. Value addition and further processing

Even after having vast scope for the meat processing industry, the processing industry is still in the infant stage. Processing meat to value added products will provide reasonable returns from meat animals to the farmers (Kondaiah, 2004). There is very little processing in India, hardly 2% of the total meat produced except 10% in poultry and remaining meat are sold in fresh or frozen form (Guleria et al. 2015). Meat processing and retailing are issues with regards to food safety standards and adverse environmental impact which can be dealt with by regulation and raising awareness among butchers, shoppers and traders. We need to focus on changing the demand for chilled processed meat, because as long as hot meat consumption practice continues it will be a way for people to trade in fresh meat at wet markets.

7. Dairy value chain

Dairy farming is considered as an appropriate aligned earning resource for scattered, fragmented and unorganized small and marginal milk producers in the Indian rural economy. The livelihood of two-third of rural population is dependent on the livestock sector, which provides support as a primary or secondary source of earning. The livestock sector provides a livelihood for around 600 million rural families out of which 70% are small and marginal farmers. This sector supports 8.8% population approximately in terms of employment generation and one-third gross income of rural households. The potential of the Indian dairy sector for employment generation is around 20 million per annum, which is crucial because of increasing unemployment in the country. Thus, dairy farming has been instrumental in support of livelihood and sustenance. Participatory management by women in dairy farming is common, which provides the scope for expansion of opportunities for women in local economies. Dairy farming empowers women and supports them to assume leadership roles in planning, decision-making and execution.

The value chain process starts with the production of milk and the subsequent stages pass through aggregation, processing, manufacturing, transportation, marketing, and finally distribution (Sarkar et al., 2022). Value chain actors include input suppliers, producers, processors, traders and consumers, who are commercially engaged in the network. Apart from chain actors, there are chain supporters, who act

as service providers and help to facilitate production. These actors do not deal with the product directly but their services are essential to execute the value chain activities efficiently. These service providers include banks, microfinance institutions, insurance companies, transporters, brokers, NGOs, government agencies, and research centers. Their financial services include loans, pre-financing, shareholdings, factoring, leasing arrangements, etc.

8. Value Chain Management Practices in Dairy Industry

The steps in value chain in Indian dairy industry are as follows:

1. Supply of inputs for dairying in form of fodder, animal feed plant, veterinary aids for the animal (cattle and buffalos).
2. Milk is taken out from the mulching animal on the daily basis by the dairy farmers (large, medium and small scale farmers).
3. Collection of milk by collection centres (various milk cooperatives societies).
4. Milk collected by the cooperative societies are sent to the dairy plants where chilling of milk, processing and packaging of milk and milk product, transportation of milk and milk product is carried out.
5. The transportation of chilled milk and milk products from one place to another is done through the means of refrigerated vans, or insulated milk tankers vans of private, government and cooperatives societies.
6. Final processed milk and milk products are transported to various retails outlets, supermarkets, and to retails markets from where the processed milk and milk products finally reaches to their end customers.

Effective management of the value chain directly affects the profitability of the involved stakeholders and the satisfaction of consumers. To increase productivity and the welfare of underprivileged farmers in developing nations, modern technology must be incorporated into the milk value chain. Value chain management makes the production process and distribution process systematic and qualitative so that the final consumer gets value in terms of right product, right price at right place and right delivery. Value chain management not only delivers value in terms of quality production but it also delivers valuable information about customer satisfaction levels, market, prices, new needs and wants.

9. **Conclusion**

As the human population grows, the demand for livestock products has increased significantly from year to year. However, in the process of fulfilling these needs, there are problems related to the livestock value chain. In this context, meat and milk value chain is an important element in the food system, especially in policy analysis and intervention. Livestock development has excellent potential for providing sustainable livelihood to small farmers in India. However, there is a need for making a coordinated effort to introduce various technologies leading to good husbandry practices and development of suitable forward and backward linkages to form an efficient value chain. A strong action plan with specific roles and responsibilities, investments by various stakeholders along with targeted approach

will guide the implementation of the policy. Scientific interventions and pragmatic policies on meat production and marketing going to play key roles in sustainability of livestock production and development of meat sector. Rising consumer affluence, increasing urbanization, family dynamics, increasing exposure to various mass media and changing food habits greatly enhance the demand for fresh meat and nutritionally superior value-added products fuelling the growth of ready-to-eat livestock product sector. In milk value chain, the production may get hit following an average rise in temperature which would create scarcity of water and dry fodder for the cattle. A strategy needs to be developed to deal with the situation arising out of climate variability.

****References can be requested from the authors****

Chapter-3

Technologies and interventions for sustainable meat products processing for small scale entrepreneurs

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1. Introduction

The demand for animal-source foods is expected to increase steadily over the next 25 years, with an annual growth rate ranging from 3.67% to 5.59% across different income growth scenarios by 2047-48 (NITI Aayog, 2024). In recent years, there has also been a significant increase in global consumption of animal-based foods, and predictions indicate that India's interest in such products could potentially double by 2030. In this context, the anticipated rise in global meat protein consumption over the forthcoming decade is forecasted to surge by 14% by 2030 in comparison to the average base period of 2018-2020, primarily fuelled by increases in income and population. Projections indicate that protein availability from beef, pork, poultry, and sheep meat will escalate by 5.9%, 13.1%, 17.8%, and 15.7% respectively by 2030 (OECD & FAO, 2021). Consequently, production and processing have escalated to meet consumer needs. For instance, India is ranked as the 8th largest meat producer globally, recording a total production of 9.77 MT in 2022-23, marking a 5.62% increase from 2020-21(BAHS, 2023) and is anticipated to experience a minimum direct meat demand of 16 million tonnes and a maximum of 22 million tonnes by 2047-48 (NITI Aayog, 2024).

Furthermore, as per the recent report of the Department of Animal Husbandry and Dairying, in 2022, the revenue from the livestock sector was Rs. 15,63,399 crores in 2022, out of which 63.66% was contributed by the dairy group with revenue of Rs. 9,95,215 crores and 24.35% (Rs. 3,80,755 crores) by the meat group (BAHS, 2023). The revenue from the meat sector is collectively contributed by the meat sector (92.86%), meat products (3.46%) and by-products sector (3.68%). The revenue from the meat sector mainly comes from buffalo meat (Rs. 36,968 crores) followed by poultry (Rs. 1,70,614 crores), sheep and goat meat (Rs. 1,37,637 crores), and pork (Rs. 8,340 crores). Whereas revenue from meat products is Rs. 13,203 crores and from by-products is Rs 13,993 crores, where it comes from hides (Rs 4,262 crores) and skin (Rs 4,421 crores), and other by-products (Rs 5310 crores) (BAHS, 2023).

But the meat product processing industry is facing increasing pressure to reduce its environmental impact while meeting growing demand for sustainable and responsibly produced meat products. Global meat demand, and technology

advancements, shifting of consumer attitudes towards meat foods supply chain, and regulatory frameworks, are the newer challenges facing by meat industry. To address this challenge, innovative technologies and interventions are being developed and implemented to enhance sustainability throughout the meat processing value chain. Sustainability refers to the ability to maintain or support a process, system, or activity over time without depleting natural resources or causing harm to the environment, social structures, or economies. It involves meeting the needs of the present without compromising the ability of future generations to meet their own needs. It seems due to population increase and economic expansion, there is a greater demand for meat globally, which presents both possibilities and problems for sustainable environmental practices, resource use, and production methods. Actually, this mutually benefited for both modern meat product processing and sustainability since the meat business has benefited from technological advancements in efficiency, quality, and safety regulations, including automation, robots, data analytics, and artificial intelligence while environmental impact and other sustainability-related issues have brought eco-friendly techniques, waste minimization, and ethical animal husbandry to the forefront of public attention. Demand for slimmer cuts, organic and grass-fed choices, and additive- and preservative-free goods has increased due to shifting customer views. Thus, this lecture introduced new insight to produce and process meat and meat products sustainably through utilizing renewable resources, minimizing waste generation, reducing carbon footprint, conserving water and energy, promoting eco-friendly practices, supporting fair labor practices, encouraging community engagement and fostering innovation and technology. Since, involves finding a balance between environmental, social and economic sustainability it is logical that it will help to create a more equitable, resilient, and thriving world for all. By adopting sustainable practices, we can help ensure a healthier planet, social equity, and economic prosperity for generations to come.

2. Principles of sustainable meat products processing

There are three key pillars of sustainability which are integrating each other for sustainable production of meat and meat products. These includes-

2.1. Environmental sustainability: Environmental sustainability through processing of meat products involves adopting practices that minimize environmental impacts. Meat processing companies can reduce their environmental footprint, promote sustainability, and contribute to a more environmentally conscious food system.

2.2. Social sustainability through processing of meat involves adopting practices that promote fair labor conditions, support local communities, and ensure ethical treatment of animals. Meat processing companies can contribute to social sustainability, promote ethical practices, and support the well-being of employees, communities, and animals.

2.3. Economic sustainability through processing of meat products involves adopting practices that promote financial viability, stability, and growth, while also ensuring long-term economic benefits for stakeholders.

3. Innovative Technologies to Support Sustainable Meat Processing for Small-Scale Entrepreneurs

3.1. Energy-efficient equipment: Energy efficient equipment like refrigeration systems, pumps, and lighting etc. can be suitable for small scale meat processing. An energy-efficient refrigeration system is a cooling system designed to minimize energy consumption while maintaining optimal temperature control. These systems use advanced technologies and design principles to reduce energy usage, lower greenhouse gas emissions, and decrease operating costs. The characteristics of energy-efficient refrigeration systems include use less energy to compress refrigerants, have lower global warming potential and higher efficiency, improves heat transfer and reduces energy consumption, monitor and adjust temperature, pressure, and flow rates, reduce water usage and energy consumption etc. The refrigeration systems are up to 50% reduction in energy consumption, reduced greenhouse gas emissions, lower operating costs, improved temperature control and product quality and reduced wear and tear on components. It includes inverter-driven refrigeration systems, CO_2-based refrigeration systems, ammonia-based refrigeration system, air-cooled chillers, evaporative cooling systems etc. By adopting energy-efficient refrigeration systems, businesses can reduce their environmental impact, lower energy costs, and improve their bottom line.

3.2. Water conservation systems: Efficient utilization of water through water recycling and adopting efficient cleaning systems could reduce water consumption by up to 50%. Treating and reusing of water from processing, cleaning, and cooling operations is a good idea for better utilization of water while installing low-flow nozzles, valves, and pumps could minimize water usage in cleaning and processing operations. Further, implementing dry cleaning methods or use of water-efficient cleaning operations like foam cleaning or misting systems, use air-cooling or evaporative cooling systems instead of water-cooling systems, implementing water recovery systems to collect and treat water from processes like chilling, washing, and cooking and rainwater harvesting substantiate effective and generous utilization of water in meat and meat product processing plants. In the recent years, it has been reported that water auditing and implement water-efficient technologies like membrane bioreactors, advanced oxidation, or UV treatment are efficient for water conservation but they must meet regulatory compliance for water reuse and recycling. These water conservation strategies and technologies can be implemented in meat products processing to reduce water consumption and improve sustainability.

3.3. Waste reduction and valorization: Waste reduction and valorisation in meat processing plants involve implementing strategies to minimize waste generation and convert waste into valuable products. It has been estimated that nearly half of the by-products from meat processing are inedible, leading to significant losses in potential revenue and leads to environmental load (Limeneh et al., 2022). Valorization entails extracting the utmost value from by-products resulting from the slaughter process by converting both edible and inedible materials into value-added products. This approach not only reduces environmental impact but also generates new revenue streams and improves sustainability. Meat processing plants can optimize processing techniques, implement efficient cleaning methods, and minimize packaging waste to reduce waste generation. Additionally, they can valorize waste by recovering meat from bones and trimmings, processing fat and bone into valuable products like tallow or bone meal, and converting blood into blood meal or plasma. The tallow is also used in feeds, soaps, detergents, biodiesel and sustainable aviation fuel. Other valorisation options include composting organic waste, anaerobic digestion to produce biogas and digestate, and insect-based conversion of waste into protein-rich animal feed or fertilizers. The biofuel can be generated from the ruminal undigested content after dewatering and proper drying. It is estimated that a large amount (about 45 kg) of ruminal undigested content is generated per animal. The calorific value of dried ingesta is 2800 Kcal/kg and can contribute an estimated value of Rs. 4/kg which is near to corresponding value of wood chips of Rs. 5/kg. Thus, it is estimated that 45 kg of raw ingesta produces 15 kg of dried ingesta (with 20% moisture) which adds revenue of Rs. 60 per animal to the exchequer. liquid waste/effluent from slaughter can also be processed to generate biogas. It is estimated that 1 KL of slaughterhouse effluent can generate up to 1.5 m^3 of biogas per day and it is equivalent to 3 kg of LPG gas. As average cost for per kg of LPG gas is about Rs. 71, and thus, a 1000 KL capacity of UASBR (Upflow Anaerobic Sludge Blanket Reactor) produced 1500 m^3 Biogas/day which is equivalent to 750 kg of LPG gas or interns of monitoring benefits of Rs. 53,000 per day or Rs. 16 lakhs per months.As a whole sustainability of the animal food sector can be achieved by 5-R approach- i.e., Reduce, Reuse, Recycle, Recover and Residual management. The 5-R approach meets the requirements of the Ecologist, Environmentalist and Economist at the same time to ensure sustainability. It is also a need of hours to process solid and liquid wastes generated from slaughterhouses to prevent or reduce environmental pollution, keep rural villages, towns and cities very clean and aesthetic and protect human health from various solid and liquid waste-related diseases. Reuse of non-bio waste through proper recycling techniques makes the flexibility of slaughterhouse viability while the conversion of bio-wastes into energy fuels like biogas makes it more sustainable and energy efficient.

By adopting these strategies, meat processing plants can reduce waste disposal costs, increase revenue, and enhance their brand reputation while complying with

regulations and standards. Effective waste reduction and valorisation can also contribute to a more circular economy and sustainable food system.

Figure: 5-R concept to utilize wastes (Source: Unsustainable, 2020)

3.4. Renewable energy sources: Aquaponics, a system combining aquaculture and hydroponics, can be powered by solar, biogas, or wind energy for sustainable meat processing. Solar power can generate electricity for water pumps, aeration systems, and processing equipment. Biogas, produced from animal waste, can fuel boilers for heat and steam generation, reducing reliance on fossil fuels. Wind power can also generate electricity, particularly suitable for plants located in windy areas. Implementing these renewable energy sources can reduce energy costs, lower carbon emissions, and enhance the plant's environmental sustainability. Additionally, biogas production can utilize waste streams, minimizing waste disposal costs and generating valuable by-products like fertilizer. Solar and wind power can also provide backup energy during grid outages, ensuring continuous operation. However, initial investment costs, technology selection, and integration with existing infrastructure must be carefully considered. Overall, adopting solar, biogas, or wind power can contribute to a more sustainable and resilient meat processing industry, aligning with environmental and economic goals.

3.5. Advanced processing technologies: Advanced processing technologies are revolutionizing the meat industry by enabling the development of sustainable meat products. High-pressure processing (HPP) and pulsed electric field (PEF) technologies can enhance meat safety and extend shelf life while reducing chemical preservatives. Advanced grinding and mixing technologies, such as high-speed grinding and nano-mixing, can improve meat texture and consistency. Novel packaging solutions like active and intelligent packaging can monitor meat quality and prevent spoilage. Additionally, technologies like 3D printing and plant-based protein extrusion enable the creation of sustainable meat alternatives.

Other advancements include ohmic heating, radio frequency processing, and ultrasonic processing, which can improve meat processing efficiency, reduce energy consumption, and minimize waste. These technologies can help develop sustainable meat products with reduced environmental impact, improved nutritional profiles, and enhanced consumer appeal.

3.6. Low-Cost, Eco-Friendly Packaging Solutions: Eco-friendly packaging includes biodegradable, recyclable, and compostable materials that minimize environmental impact. Utilizing materials such as polylactic acid (PLA), cellulose-based films, and plant-based plastics can significantly reduce packaging waste. Research indicates that eco-friendly packaging can degrade within months under appropriate conditions, unlike traditional plastics that persist for centuries. It includes, reduced environmental footprint, compliance with regulatory standards, and enhanced consumer appeal

3.7. Mobile Slaughter and Processing Units: Mobile units offer on-site slaughtering and processing, reducing transportation needs and ensuring fresher products. Mobile processing units can significantly reduce stress on animals, which is linked to better meat quality. Additionally, they minimize the environmental impact associated with transporting livestock to centralized facilities. It results in, enhanced meat quality, reduced transportation costs and emissions, and increased flexibility for small-scale operations.

3.8. Small-Scale Meat Processing Equipment: Compact and versatile equipment tailored for small-scale operations, enabling entrepreneurs to diversify their product offerings. Modern small-scale equipment often incorporates automation and precision controls, ensuring consistency and efficiency. For example, programmable sausage stuffers can produce uniform products, reducing material waste. This results in, increased production capacity, product consistency, and the ability to create a variety of meat products.

3.9. Digital Platforms for Market Access and Sales: Online marketplaces, e-commerce websites, and digital marketing tools that connect producers directly with consumers. Digital platforms utilize data analytics and consumer behaviour insights to optimize sales strategies. Social media integration and search engine optimization (SEO) enhance visibility and reach. This leads to, expanded market reach, increased sales, and improved customer engagement and loyalty.

4. Interventions for Sustainable Meat Processing

4.1. Supply chain optimization: Supply chain management has greater role in sustainable meat products processing. To improve logistics, sourcing, and distribution in supply chain optimization for meat products, implements a multi-faceted approach. Start by streamlining logistics through efficient transportation

management, optimizing routes, and leveraging real-time tracking and monitoring systems. Enhance sourcing by developing strategic partnerships with reliable suppliers, implementing a robust supplier selection process, and ensuring compliance with food safety and quality standards. Improve distribution by investing in advanced warehouse management systems, implementing just-in-time delivery, and utilizing data analytics to optimize inventory management. Additionally, consider implementing a centralized distribution network, leveraging third-party logistics providers, and investing in cold chain management to ensure product quality and safety. Furthermore, adopt sustainable practices, such as reducing packaging waste and implementing environmentally friendly transportation methods, to minimize environmental impact. By integrating these strategies, meat product suppliers can reduce costs, enhance efficiency, and improve customer satisfaction, ultimately leading to a more optimized and resilient supply chain.

4.2. **Quality control and assurance**: At present day, consumers are more health conscious. They feel meat products that produce and consumed should pass through stringent quality inspections and monitoring systems. So, it is required to implement HACCP (Hazard Analysis and Critical Control Points), GMP (Good Manufacturing Practices), and SSOP (Sanitation Standard Operating Procedures) for quality control and assurance of meat products, which should start by conducting a thorough hazard analysis to identify potential risks. A robust HACCP plan that outlines critical control points, monitoring procedures, and corrective actions required to develop. Similarly, implementation of GMPs by establishing clear guidelines for personnel hygiene, equipment maintenance, and facility cleanliness should be mandatory to follow during meat products processing. Development of SSOPs should be placed and required to be followed in meat processing establishment for sanitation and cleaning schedules, ensuring that all equipment and surfaces are properly cleaned and sanitized. Train personnel on all procedures and ensure that they understand their roles in maintaining quality control. Establish a system for monitoring and recording critical control points, and conduct regular audits to ensure compliance. Verify the effectiveness of the HACCP plan through testing and validation, and make adjustments as needed. Finally, maintain accurate records of all quality control activities, and continuously review and update the HACCP plan, GMPs, and SSOPs to ensure ongoing compliance with regulatory requirements and industry standards, ensuring the production of safe and quality meat products.

4.3. **Certification and labeling**: In India, to obtain organic, halal, or animal welfare certification for meat products, producers must follow specific procedures. For organic certification, register with the National Programme for Organic Production (NPOP) or the Participatory Guarantee System (PGS) and meet their standards. For halal certification, apply to a recognized halal certification body

such as the Halal Certification Council of India or the Jamiat Ulama-i-Hind Halal Trust. For animal welfare certification, register with the Animal Welfare Board of India. Submit required documents, including farm or facility details, production processes, and animal handling practices. Undergo an inspection and audit to verify compliance with certification standards. Once certified, obtain a certification mark and label products accordingly. Renew certification as required. Additionally, register with the Food Safety and Standards Authority of India (FSSAI) for food safety certification. Compliance with these certifications ensures that meat products meet quality, safety, and ethical standards, enabling access to domestic and international markets. Producers can also leverage certification to differentiate their products and enhance brand reputation.

4.4. Market access and development: To connect with buyers and create effective marketing strategies for market access and development, it's essential to understand your target audience and their needs. Start by conducting market research to identify potential buyers, their preferences, and purchasing habits. Develop a unique value proposition that highlights the benefits of your product or service. Establish a strong online presence through social media, email marketing, and a website to showcase your offerings and engage with potential buyers. Build relationships with key industry players, attend trade shows and events, and leverage networking opportunities to expand your reach. Craft a tailored marketing strategy that incorporates digital marketing, content marketing, and traditional advertising to reach your target audience. Utilize data analytics to track performance, refine your approach, and make data-driven decisions. Finally, foster strong customer relationships through excellent customer service, timely communication, and personalized support to drive loyalty and repeat business. By implementing these strategies, you can effectively connect with buyers, expand market access, and drive business growth.

4.5. Networking and Industry Connections: Facilitating connections between small-scale entrepreneurs and industry stakeholders, including suppliers, distributors, and other meat processors. Social network theory emphasizes the importance of building robust networks for knowledge exchange, resource sharing, and collaborative innovation. Networking can lead to partnerships that drive mutual growth and sustainability. This results in, access to valuable resources, collaborative opportunities, and enhanced industry presence

4.6. Environmental Impact Assessments and Mitigation Strategies: Conducting assessments to evaluate the environmental impact of meat processing operations and developing strategies to mitigate negative effects. Environmental impact assessments (EIAs) utilize scientific methodologies to measure factors such as greenhouse gas emissions, water usage, and waste generation. Mitigation strategies based on sustainability science can significantly reduce environmental

footprints. General mitigation strategies for reducing the environmental impact of meat production, including improving feed efficiency, enhancing pasture management, optimizing feedlot practices, reducing land use change impacts, investing in carbon offsetting, and improving animal health and breeding. Thus leading to, improved environmental performance, compliance with environmental regulations, and enhanced corporate social responsibility

5. Challenges and Opportunities

5.1. Limited access to finance: The upfront costs for sustainable technologies in processing of meat products can vary widely depending on the specific technology and scope of implementation. However, some common costs include: equipment purchases or upgrades, such as energy-efficient refrigeration systems, LED lighting, or advanced water treatment systems; installation and commissioning costs; training and certification for personnel; costs associated with modifying facilities or processes to accommodate new technologies; and costs related to obtaining certifications, such as organic or halal. Additionally, costs may be incurred for consulting services, audits, and assessments to identify areas for improvement and ensure compliance with sustainability standards. Initial investment costs can range from 5% to 20% of total processing costs, depending on the technology and scope of implementation. For example, upgrading to energy-efficient equipment may require an initial investment of $50,000 to $200,000, while implementing a comprehensive water conservation system may require an investment of $100,000 to $500,000. However, these costs can be offset by long-term savings in energy, water, and waste management, as well as improved brand reputation and market access.

5.2. Lack of technical expertise: The meat processing industry faces several technical challenges in sustainable processing of meat products, including optimizing energy and water usage, reducing waste and emissions, and implementing efficient processing technologies. One major challenge is maintaining product quality and safety while reducing energy consumption and environmental impact. Additionally, implementing sustainable practices such as recycling and reusing water, and reducing packaging waste, can be technically complex and require significant investments in new equipment and processes. Another challenge is developing cost-effective and efficient technologies for reducing greenhouse gas emissions, such as capturing and utilizing biogas from animal waste. Furthermore, ensuring consistent and reliable supplies of sustainable raw materials, such as feed and ingredients, can be difficult. Implementing sustainable processing technologies, such as high-pressure processing and pulsed electric field processing, also requires significant technical expertise and investment. Finally, ensuring compliance with evolving regulatory requirements and industry standards for sustainability and environmental impact can be a technical

challenge. Addressing these technical challenges will be crucial for the meat processing industry to achieve sustainable processing practices.

5.3. Scalability and replicability: Small-scale processing of meat products faces significant adaptability problems due to limited resources, infrastructure, and expertise. These processors often struggle to adapt to changing regulatory requirements, consumer preferences, and market trends, making it difficult to remain competitive. Limited access to financing, technology, and training hinders their ability to invest in new equipment, processes, and staff, making it challenging to improve efficiency, quality, and sustainability. Additionally, small-scale processors often lack the economies of scale to negotiate favorable prices for raw materials, packaging, and other inputs, increasing their costs and reducing their margins. Furthermore, they may not have the resources to invest in research and development, marketing, and branding, making it harder to differentiate their products and attract new customers. The lack of standardization and consistency in small-scale processing operations can also lead to variability in product quality, safety, and shelf life, making it difficult to build trust with customers and expand their business. Overall, the adaptability challenges faced by small-scale meat processors can limit their ability to innovate, grow, and remain viable in a rapidly changing market.

5.4. Policy and regulatory support: The sustainable processing of meat products requires policy and regulatory supports to create an enabling environment for adoption and scaling up of sustainable practices. Governments can play a crucial role by providing incentives, such as tax breaks, subsidies, and grants, to encourage investment in sustainable technologies and infrastructure. Regulations can be put in place to set standards for environmental sustainability, animal welfare, and social responsibility, and to ensure compliance through regular audits and certifications. Policies can also support research and development, training, and capacity building for small-scale processors to improve their competitiveness and sustainability. Additionally, governments can establish labeling and certification schemes to promote sustainable products and provide consumers with informed choices. Trade policies can also be designed to support the export of sustainable meat products, while ensuring that imports meet domestic sustainability standards. Furthermore, governments can engage with industry stakeholders to develop and implement voluntary sustainability initiatives, such as roundtables and codes of practice, to drive industry-wide change. By providing these policy and regulatory supports, governments can help level the playing field for sustainable meat processors and drive the industry towards a more sustainable future.

5.5. Consumer awareness and demand: Consumer awareness and demand play a crucial role in driving the adoption of sustainable processing practices in the meat

industry. As consumers become increasingly conscious of the environmental, social, and health impacts of their food choices, they are seeking out products that align with their values. Growing demand for sustainable meat products can incentivize processors to adopt more sustainable practices, such as reducing waste, using renewable energy, and implementing humane animal handling practices. Consumer awareness campaigns can educate shoppers about the benefits of sustainable meat production, including improved animal welfare, reduced environmental impact, and enhanced nutritional quality. Labeling schemes, such as "grass-fed" or "regeneratively raised," can help consumers make informed choices. Moreover, consumer demand for transparency and accountability can push processors to prioritize sustainability and report on their environmental and social performance. As consumers increasingly prioritize sustainability, their purchasing decisions can drive industry-wide change, encouraging more processors to adopt sustainable practices and creating a more resilient and responsible meat industry. By driving demand for sustainable meat products, consumers can help create a market that rewards sustainable production and processing practices.

6. Conclusion

Sustainable meat products processing is crucial for small-scale entrepreneurs to improve their environmental, social, and economic performance. By adopting energy-efficient technologies, waste reduction strategies, and renewable energy sources, small-scale meat processors can reduce their environmental footprint. Interventions like training, supply chain optimization, and certification can enhance their competitiveness and market access. Addressing challenges like finance, technical expertise, and policy support can help small-scale entrepreneurs adopt sustainable practices and contribute to a more sustainable food system.

****References can be requested from the authors****

Chapter-4

Certified Organic Meat Production and Processing in India-prospects and the Way Forward

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1. Introduction

As per the available statistics, India ranks 2nd in terms of World's Organic Agricultural land and 1st in terms of total number of producers (FIBL & IFOAM Year Book, 2024). As on 31st March 2024, total area under organic certification process (registered under National Programme for Organic Production) is **7.3 million ha** (2023-24). This includes **44,75,836.91 ha** cultivable area and another 28, 50,156.48 ha for wild harvest collection. India produced around **3.6 Million MT** (2023-24) of certified organic products which includes all varieties of food products namely Oil Seeds, fibre, Sugar cane, Cereals & Millets, Cotton, Pulses, Aromatic & Medicinal Plants, Tea, Coffee, Fruits, Spices, Dry Fruits, Vegetables, Processed foods etc. The production is not limited to the edible sector but also produces organic cotton fiber, functional food products etc. The total volume of export during 2023-24 was 2,61,029 MT. The organic food export realization was around INR 4007.91 Crore (494.80 million USD). Organic products are exported to USA, European Union, Canada, Great Britain, Sri Lanka, Switzerland, Vietnam, Australia, Thailand, New Zealand, Japan, Korea Republic etc. However, these impressive figures have only a very little contribution of organic livestock products so far. Organic livestock production is an emerging opportunity for youths, startups, enterprising & innovative farmers having potential for exports while ensuring high quality animal products to domestic consumers.

2. The Organic Livestock & Poultry Standards

Organic animal husbandry has been defined as a system of livestock production that promotes the use of organic and biodegradable inputs from the ecosystem deliberately avoiding the use of synthetic inputs such as drugs, feed additives and genetically engineered breeding inputs, while ensuring the welfare of animals. There are four principles of organic farming viz; principle of ecology, principle of health, principle of fairness, and principle of care, which organic systems must always take into consideration. In order to achieve the animal welfare, environmental protection, resource-use sustainability and other objectives, certain key principles are adhered to under organic livestock production systems.

3. Organic Animal Husbandry: The Key considerations

The major challenge in organic livestock production systems is to honour the organic principles in a wide range of diverse systems under a wide range of circumstances and conditions including systems which are not yet certified 'organic' at the moment. It's recommended that developing organic animal husbandry at all times require a thorough analysis of the problems, opportunities and existing local knowledge. Therefore, some key considerations in organic animal husbandry that producers and other stakeholders need to take into account are listed here under:

3.1. Origin of Livestock: Livestock and products from the livestock that are sold, labeled, or advertised as organic must be from livestock that originate from animals that were managed under continuous organic management from the last third of gestation or at hatching.

3.2. Livestock Feed: Livestock that are produced under organic management must have their total ration that is comprised of agricultural products including pasture, forage, and crops that are organically produced and handled organically. There are certain non-synthetic and synthetic substances that can be used as feed additives and supplements. Dairy cattle under 9 months of age are allowed 20% of their feed coming from non-organic sources. Plastic pellets, urea, manure, mammalian or poultry slaughter by-products are not allowed. The list of allowed and non-allowed feeding material is available as annexures with the organic livestock and poultry standards developed among others by Government of India.

3.3. Living Conditions: An organic livestock producer must create and maintain living conditions that accommodate natural behavior and health of the animal. The living conditions must include access to outdoors, shade, shelter, fresh air, direct sunlight suitable to the species, and access to pasture for ruminants.

3.4. Waste Management: Organic livestock producers are mandated to manage manure so that it does not contribute to the contamination of crops, soil, or water and optimizes recycling of nutrients.

3.5. Health Care*:* Organic livestock production practices require the producer to establish preventative health care practices. The health care practices include selecting the appropriate species and type of livestock, providing adequate feed, create an appropriate environment that minimizes stress, disease, parasites, administration of vaccines and veterinary biologics and animal husbandry practices to promote animal wellbeing in a manner that minimizes pain and stress. Producers cannot provide preventative antibiotics. Producers

are encouraged to treat animals with appropriate treatment, including antibiotics and other conventional medicines when needed but treated animals cannot be sold or labeled as organic. Producers cannot administer hormones or other drugs for growth promotion.

3.6. Record Keeping/Audit Trail: Organic livestock operations need to maintain records for a number of reasons. Apart from financial management of the organic livestock enterprise, records are important for the verification of organic status of animals, production, harvesting, and handling practices associated with the organic products and animals. Records are mandated to be maintained for 5 years, and must demonstrate compliance with the organic food production standards and acts, if any in place.

Under organic livestock production systems, it is expected that- organic milk, meat, poultry, eggs and products thereof come from farms that have been inspected to verify that they meet rigorous standards which mandate the use of organic feed, prohibit the use of antibiotics, give animals' access to outdoor, fresh air and sunlight. The production methods are selected based on criteria that meet all health regulations, work in harmony with the environment, build biological diversity and foster healthy soil and growing conditions. After the production, animals are marketed that were raised without use of toxic persistent pesticides, antibiotics and paraciticides. Animal health, well being, better living conditions, welfare measures, feeding practices are to be ensured through a set of standards and maintenance of written records by the organic livestock farmers. Better managemental practices and prevention are emphasized over treatment. Thus, the primary characteristics of organic livestock production system are: a defined standard; greater attention to animal welfare; no routine use of growth promoters, animal offal or any other additives; at least 80% of feed grown according to organic standards, without the use of artificial fertilizers or pesticides on the crops or grass. To be precise, organic meat, milk and eggs means that are produced, harvested, preserved and processed as per organic standards. Anyone wishing to switch over or convert to organic farming need to follow the organic standards developed among others by Government of India under National Programme for Organic Production (NPOP).

Organic production systems are knowledge and skill intensive, where the producers are expected to be knowledgeable about production norms, standards and practices for production and processing prescribed under approved standards by the designated authorities viz APEDA, BIS, FSSAI etc. It is expected from the organic producers that they are not only familiar with organic livestock standards, but also well versed in good agricultural/livestock production practices, animal welfare standards, regulatory requirements as applicable to livestock and food production in general. At one end, there is traditional animal husbandry, while conventional production system in between and the most innovative one i.e. organic animal

husbandry is the latest system. The farmers wishing to switch from traditional and conventional animal production systems to organic animal husbandry need information, knowledge and skills to follow organic livestock and poultry standards, where there exists currently a big gap. Field level extension functionaries need to have wider awareness and knowledge about organic animal husbandry standards for onward dissemination of information and orientation of the stakeholders involved in livestock production.

4. Organic Food Products & Consumers

The organic agricultural products including of livestock origin are gaining increasing popularity. The farmers can cash upon this growing interest in eco-friendly, animal welfare oriented, safe, nutritious and tastier meat products (as perceived by consumers of organic products). The eggs and meat obtained from such venture can be promoted as specialty item to restaurants; hotels and ethnic food jaunts fetching higher returns, better when local/*deshi* birds are raised, which can better perform in free range system. Poultry can utilize the grazing lands/plantation areas (Rubber, coffee, coconut etc) by feeding on earth worms, small insects, green grass etc, while fertilizing the land with manure.

The free range poultry systems or pastured poultry is a sustainable agriculture technique that calls for the raising of laying chickens, broilers and turkeys on pasture, as opposed to indoor confinement. Humane treatment, the perceived health benefits of pastured poultry, in addition to superior texture and flavor, are causing an increase in demand for such products, which are believed to be having medicinal value, rich in antioxidants and least in chemical, medicinal or hormonal residues. Therefore, the growing interest in organic farming and meat & eggs drawn from free range systems might offer an attractive option in the form of market premiums for livestock farmers to venture into organic production.

Educating consumer and producer both is important to promote organic livestock production. Consumers need to be told that the safe milk and meat that they are looking for is the certified organic milk and meat, while farmers need to be made aware of this demand to be able for them to translate it into the new market opportunity. Also, there is a small but very concerned section of the society who does not consume livestock products owing to issues of animal cruelty, ill-treatment with them etc. The organic rearing of the farm animals sincerely addresses these issues and the certifiers approve that the due care has been taken in the process of production. These standards ensure that animals are kept free or never tied without specific purpose, allowed to express their physiological behaviour, fed with chemical free fodder, are not given hormonal injections and are reared in a completely stress free atmosphere. The information gap with respect to organic animal husbandry at the level of produces and consumers need to be bridged by suitable extension education interventions and encouraging the farmers, milk brands, cooperatives to enter this market on one side and consumers at the other end.

5. The current scenario

There are 52 certified organic dairy operators, 66 meat operators & 3 certified egg operators in India. The information on domestic sales of organic livestock products indicate the availability of certified organic milk and milk products in India (Table1). Also, India exported 2125.6 kg of certified organic *Ghee* (Clarifed butter) to UAE during 2019-20. India recently exported about 50MT of certified organic cheese to UAE. Animals not only produce products for direct human consumption, but also help produce organic by-products like cattle urine & cow dung used to enhance soil fertility.

Table1: Production & sales of certified organic milk & milk products in India (2019-20).

S.NO.	Item	Quantity MT(Metric Ton)
1.	Milk	16050
2.	Ghee (Clarified butter)	400
3.	Butter	9
4.	Milk Cream	390
5.	Skiimed Milk	320
6.	Skiimed milk powder	660

At ICAR-Indian Veterinary Research Institute as well as several other animal science research institutes and Veterinary Universities/colleges initiatives are underway to promote organic animal husbandry. For instance, the ICAR- National Research Centre on Meat got its organic sheep unit certified having the knowhow to handhold and guide the prospective farmers through all the processes involved in taking up organic sheep farming and certification. Out of total 32 accredited certification bodies (CBs) in India, 7 CBs are accredited for certification of livestock & poultry. It has taken initiatives to train certification bodies and evaluation committee to inspect & audit organic livestock operations. The author has been associated with all such capacity building programmes undertaken by APEDA to develop organic animal husbandry in India. Also, he has been training the Inspectors of certification bodies on certification process for organic livestock products. The start-ups, entrepreneurs including the farmers wishing to convert to organic animal husbandry need to be aware of the conversion, production & certification procedures for organic livestock production (Prakati 2020).

The Government of India is supporting several projects on organic agriculture that includes organic animal husbandry too. At the Agribusiness Incubation Cell (ABI) of ICAR- Indian Veterinary Research Institute, project proposals are invited for nurturing/incubating. The selected candidates are regularly mentored & financially supported to further develop the proposals including on organic production having market potential. They are trained on the topics like product development, branding, market assessment, launching in the market, winning consumers' confidence, product innovation, labeling, packaging, managemental aspects, record keeping etc. The

trainees, wishing to start organic livestock and poultry production, are mentored through capacity building programmes. They are being introduced to the established certified organic farmers and export value-chains for awareness, knowledge and opportunities in the sector. The trainees are often very apprehensive of export markets for organic livestock products which have serious challenges mainly due to existence of infectious diseases in India like Foot & Mouth Disease (FMD) which restrict export to FMD free countries mostly in developed countries.

The capacity building initiatives on organic animal husbandry including mentoring of start-ups has been helping the farmers and entrepreneurs to get constructively engaged in enterprises related to organic livestock production.The startups are making organic food more accessible and affordable to the consumers, while creating new opportunities for farmers by motivating them to adopt organic livestock farming practices.Not only organic foods but the start-ups are engaged in producing value added products from animal by-products, which has attractive market in India and have possibilities of exports too. The initiatives have also been taken in India regarding certified organic sheep wool production. It would be better if pastoralist system prevailing in parts of country like barren mountainous regions/Islands/deserts/areas inhibited and managed by nomads are covered first under Participatory Guarantee System (PGS) and gradually switched to Third party certification considering the market potential of products from such areas and communities. The Sundarban in West Bengal is one good example, wherein, communities have been organized under Women Dairy Cooperative Societies and production of milk; milk products, honey etc have been certified and being marketed as 'certified organic'.

Certified organic meat production in India is an emerging sector that focuses on producing meat products without synthetic chemicals, antibiotics, or genetically modified organisms (GMOs). The production process adheres to strict standards set by certification bodies to ensure that the meat is genuinely organic and meets consumer expectations. India has potential in exporting certified organic meat, especially to countries where organic food demand is high. However, it requires adherence to international standards and rigorous quality control. The demand for organic meat in India is growing, driven by increasing health awareness and concerns about food safety. Organic meat products are available through specialized stores, online platforms, and select retail outlets. The market is still niche, but it is expected to grow as more consumers seek healthier and environmentally friendly food options

6. **Challenges in certified organic meat production**
    - High production costs and limited availability of organic feed are significant challenges.
    - The certification process can be complex and time-consuming, which may deter small farmers from entering the market. The certification process includes stringent checks on farming practices, feed quality, animal welfare, and processing methods. High emphasis is placed on

maintaining the natural living conditions and humane treatment of animals.

- There is also a need for better awareness and education about the benefits of organic meat among consumers

Overall, while certified organic meat production in India is still developing, it holds promise for the future as more farmers and consumers recognize its benefits.

7. **Conclusion**

Organic animal husbandry research & developmental activities are largely concentrated in countries in EU and some other developed countries. Yet, developing countries like China, Mexico and Brazil are main exporting countries of eggs & Honey to EU. Bovine meat and non-edible animal products are imported from Uruguay. Organic sheep and goat meat originate from New Zealand, while cheese is imported in EU from the USA (Willer et al 2021 & Chander et al 2011). This shows the potential for countries like India to export organic livestock products to EU and other developed countries. Certified Organic animal products are being supplied by several companies in India with growing demand. When the quality conscious consumers are looking for organic animal products, domestic sales and exports is picking up, it calls for efforts to promote organic animal husbandry.

****References can be requested from the authors****

Chapter-5

Farm-to-Fork Traceability System for Meat Food Quality and Safety Assurance

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1. Introduction

Livestock traceability has become essential in the modern food system, enhancing both animal and human health, as well as consumer trust and market access. Defined by the FAO (2007) as the capability to track an animal product through every production stage back to its origin, livestock traceability involves monitoring individual or groups of animals throughout their lives (OIE, 2018). This practice is key to effective food safety management (Schroeder and Tonsor, 2012). According to ISO 22005, traceability encompasses tracking a food product across all production, processing, and distribution phases. It benefits consumers by providing information on meat origins, fostering trust in the production process, and enabling authorities to quickly identify and isolate contaminated products for better foodborne disease control (Smith et al., 2008). Moreover, effective traceability systems facilitate targeted recalls, reducing consumer risk and protecting brand reputation.

The global demand for transparency and accountability in food production has made traceability crucial for market access. Traditionally, meat and livestock products were sold as generic commodities, but crises like the Bovine Spongiform Encephalopathy (BSE) outbreak in Europe highlighted the need for stronger food safety measures (OIE, 2018). Consequently, many developed countries now mandate national traceability systems for market entry. This requirement is particularly significant for buffalo meat exporters such as India. Despite being the top exporter of buffalo meat, India's share in the global market remains modest, partly due to the lack of a comprehensive traceability system. To address this, the Indian government has launched initiatives to improve traceability. Countries with stringent food safety standards often require certifications like ISO 22000:2005 and ISO 22005 for imports. By implementing a robust traceability system, India could enhance food safety and bolster its reputation as a reliable global exporter.

Implementing a comprehensive livestock traceability system offers numerous benefits, including improved market access, enhanced consumer trust, better food safety, and stronger disease control. Adopting traceability supports a sustainable and accountable future for the global meat industry, fostering strong consumer relationships and new market opportunities. This chapter delves into the importance

of meat traceability, highlighting its positive effects on industry sustainability and consumer confidence.

2. Advantages of Implementing a Livestock Traceability System

To consumers, "meat traceability" means knowing where their meat comes from and trusting a reliable system that ensures safe production. A complete traceability system enables tracking both forward (farm to fork) and backward (plate to farm) (Girish et al., 2013). These systems improve animal husbandry practices worldwide, by promoting animal health, ensuring food safety, facilitating market access and supporting informed decision-making, paving the way for a more sustainable and secure future. Here are the benefits of implementing a traceability system:

2.1. Enhanced Animal Health and Disease Management

Traceability is vital for disease monitoring and control. When a disease is found, the system quickly identifies the farm of origin (Johnston, 2004), allowing targeted disease control and biosecurity measures, which minimize economic impacts (Herrero et al., 2013). It also helps pinpoint sources of chemical contaminants, improving food safety (Thakur and Hurburgh, 2009).

2.2. Improved Food Quality and Consumer Trust

Traceability supports strong quality assurance programs by tracking important activities like vaccinations and deworming in real-time, ensuring best practices and resulting in healthier animals and safer meat (Shackell et al., 2001). This transparency in food safety measures builds consumer confidence.

2.3. Increased Efficiency and Productivity

Using animal identification data with performance tracking software allows breeders to make informed decisions based on individual animal and offspring data. This approach enhances selective breeding practices, leading to higher quality and productivity in herds over time.

2.4. Efficient Government Programs and Market Expansion

Centralized traceability databases provide critical information for government agencies to efficiently manage animal husbandry support programs and conduct accurate livestock counts, reducing costs and manpower needs. Complying with traceability standards is essential for exporting to countries with strict regulations, opening new market opportunities for livestock products.

2.5. Empowering Stakeholders with Information

Traceability systems connect farmers, processors, and consumers with valuable information. Farmers receive timely reminders for essential farm tasks, while consumers gain insights into meat origins and production methods. This transparency builds trust and enhances the overall livestock production process.

3. Traceability by identification of animals

Livestock traceability systems heavily depend on animal identification, which entails assigning unique identifiers to animals or groups for tracking throughout the supply chain. Selecting the appropriate identification method is crucial and should consider

factors such as durability, cost-effectiveness, ease of implementation, and resistance to tampering (Frewer et al., 2005).

3.1. Traditional Methods:

I. Permanent Methods:

a. Ear Notching: Ear notching, a traditional livestock identification method, involves creating V-shaped incisions in the ear to encode unique identifiers. Notches in the right ear signify litter numbers, while those in the left ear denote specific animals within the litter. While cost-effective and visible, ear notching can be painful, alter animal aesthetics, and lacks scalability and data tracking capabilities.

b. Hot Branding: Hot iron branding, another traditional method, uses heated metal stamps to mark animals. While permanent, it causes discomfort and scarring, making it less effective over time. Concerns about animal welfare have led to bans in some countries.

c. Freeze Branding: Freeze branding induces white hair growth in branded areas, offering a less painful alternative to hot branding. However, it may not be suitable for white animals and can be obscured by coat colour changes.

d. Ear Tattooing: Ear tattooing involves placing ink into ear holes to create alphanumeric identifiers. While permanent, it is susceptible to alteration, duplication and laborious recording processes.

II. Temporary Methods:

a. Ear Tagging: Ear tags, made from metal or plastic, provide visual identification. Despite their convenience, they can cause harm during application, lack automatic data recording and are prone to damage and loss.

III. Electrical Method:

a. Radio Frequency Identification (RFID) Tags: RFID tags enable contactless, long-distance reading and are available in various forms. While offering benefits like remote monitoring and improved efficiency, they require configuration and carry implementation costs.

3.2. Advanced Methods:

a. Quick Response (QR) Code Tags: QR code tags store extensive data and can be scanned with smartphones. They enhance traceability, quality control and consumer confidence by providing real-time information.

b. Iris Patterns: Iris recognition offers unique identification but faces challenges with animal movement and image quality. Research aims to improve feasibility for livestock identification.

c. Retinal Vascular Patterns: Retinal scans offer reliable and tamper-proof identification but requires close contact with animals and face processing challenges.

d. Muzzle Point: Muzzle prints, like fingerprints, provide stable identification. Recent advancements in image recognition enhance accuracy, making them a promising identification method.

4. Livestock traceability

4.1. Livestock traceability around the world

Around the world, livestock traceability systems have become essential for ensuring safe food and building consumer trust. These systems not only ensure food safety but also help consumers know where their meat comes from, building trust in the process.
a. European Union (EU): After the BSE crisis, the EU introduced TRACES, a system that tracks animal movements and ensures beef is labeled with origin information.
b. Australia: Australia's NLIS helps monitor cattle health and food safety by recording all animal movements using RFID ear tags or rumen boluses.
c. Japan: Japan's traceability system, introduced after a BSE case, requires unique ear tags for cattle and provides traceability information to consumers, promoting trust in meat quality.
d. Uruguay: Facing a meat export crisis due to disease outbreaks, Uruguay implemented a traceability system in 2006. Livestock producers receive unique registration numbers for tracking their animals, which has boosted meat prices and expanded export markets.

4.2. Livestock traceability in India

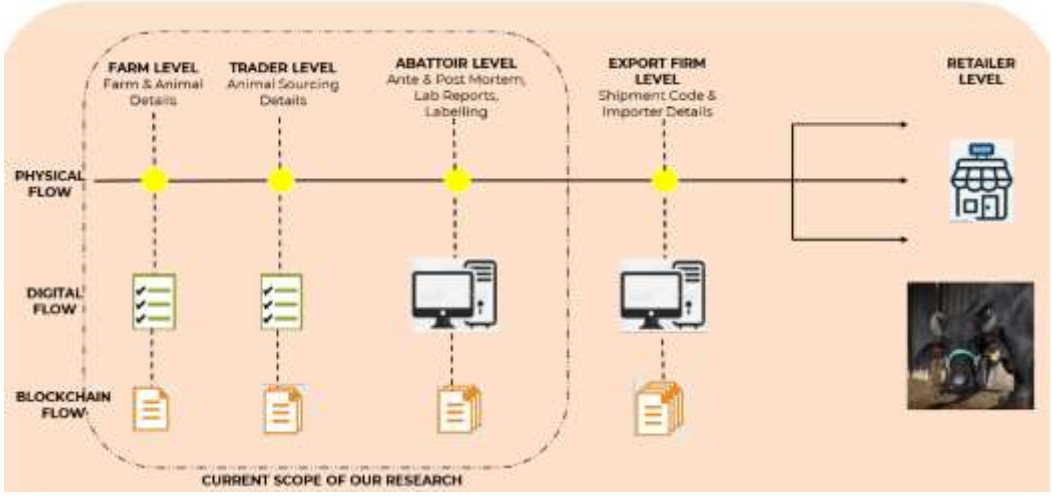
India, known as the world's largest exporter of buffalo meat, is actively embracing livestock traceability initiatives to ensure food safety, consumer trust, and market access. The journey began in 1989 when the National Dairy Development Board (NDDB) collaborated with milk unions in Gujarat State to implement progeny testing projects, which mandated ear-tagging of animals with unique identification tags. This pioneering effort used a COBOL-based information system to manage data. NDDB later strengthened its initiatives by establishing the Information Network for Animal Productivity and Health (INAPH) in 2008, originally focused on dairy animal identification and performance recording. In 2017, INAPH expanded nationwide under the Department of Animal Husbandry & Dairying, significantly enhancing India's traceability capabilities (Shivanagowda et al., 2023).

INAPH aims to document all animal transactions linked to their unique 12-digit identification number, complying with guidelines from the International Committee for Animal Recording (ICAR). While ICAR guidelines typically call for a 15-digit ID, INAPH utilizes a 12-digit ID incorporating India's code internally for global data compatibility. Meat.Net, launched by the Agricultural and Processed Food Products Export Development Authority (APEDA) alongside NDDB's efforts, focuses on certifying post-slaughter meat quality in export abattoirs to meet international standards (Navya et al., 2022).

At the state level, Maharashtra State has been at the forefront of animal identification through the Maharashtra Animal Identification and Recording Authority **(MAIRA)**, led by the Maharashtra Livestock Development Board (Ruhil et al., 2013). **MAIRA** contributes to the broader national traceability framework.

MeatTrace, a blockchain-based traceability system developed by ICAR-National Research Centre on Meat, Hyderabad in collaboration with M/s Chainflux, Bengaluru. The system aims to enhance transparency in meat exports. This groundbreaking platform enhances traceability in the buffalo meat supply chain, specifically at the slaughterhouse level, by integrating live animal data from the INAPH database using

blockchain technology. '**MeatTrace**' ensures comprehensive traceability from farm to fork within the buffalo meat industry, leveraging blockchain benefits such as data immutability and transparent traceability. By scanning a QR code on the packaging, consumers can verify product authenticity in real time. The system, currently tracking animals tagged through INAPH, offers benefits such as tamper-proof data, complete traceability, improved supply chain quality control, efficient product recalls, and early disease detection. It also enhances export potential by providing end-to-end traceability.



The **M-Anitra** app, developed for Mithun, is a digital tool aimed at enhancing the management and care of Mithun, a semi-domesticated bovine species. The app provides features for tracking animal health, nutrition, and breeding, and allows farmers and researchers to monitor the well-being of Mithun herds. By offering real-time data and actionable insights, M-Anitra aids in improving productivity and sustainability in Mithun farming, ensuring better management practices and contributing to the conservation of this valuable species.

m-anitra
Adding Value to Mithun

For meat exports, traceability is mandatory for all export-oriented abattoirs certified under Food Safety Management System Standards like ISO 22000:2018. Animals slaughtered for export are tagged with details referencing their source animal's ear tag number, and each food package bears a batch or reference number linked to the carcass tag for movement tracking throughout the supply chain. Traceability data is electronically recorded for easy access, maintaining quality standards for importing countries.

Recently, the '**Bharat Pashudhan app**' was launched under the National Digital Livestock Mission (NDLM) in 2024. This digital database for livestock animals assigns a unique 12-digit Tag ID to each animal, empowering farmers with a traceability system for bovines and facilitating disease monitoring and control.

5. **Traceability: Methods for Confirming Meat Origin**

When it comes to verifying where meat comes from, traditional methods based on inventory records can sometimes fall short. That's where molecular meat traceability comes in, offering a more dependable way to confirm meat origin by comparing the DNA of a meat sample with a reference sample taken at the time of slaughter. The key here is keeping those reference samples safe until the meat is consumed. Molecular meat traceability relies on the fact that each animal has its own unique DNA code, which stays the same throughout its life. DNA is handy for this job because it's stable across different tissues, processing methods, and storage temperatures, plus it's found in every cell of the animal.

Two common techniques used for molecular meat traceability are Microsatellite genotyping and Single Nucleotide Polymorphism (SNP) genotyping. Microsatellites are short, repetitive DNA sequences with variations in length between individuals. SNP genotyping zeroes in on identifying single base variations within the DNA sequence. Both methods involve extracting DNA from the meat sample and a reference sample, then comparing their genetic profiles.

5.1. Meat Traceability using microsatellite markers

Microsatellite markers, also known as short tandem repeats, are short segments of DNA that repeat one to six nucleotides. These repeats can mutate during DNA replication, offering a unique identifier for each animal. Microsatellites are analyzed using PCR to amplify specific DNA segments, revealing size variations that represent different alleles. This method is advantageous because microsatellites are stable across various conditions and easily accessible from any cell in the body.

The steps for molecular meat traceability using microsatellite markers involve selecting appropriate markers, extracting DNA from meat and reference samples, conducting PCR, and analyzing the resulting DNA fragments. These markers exhibit high allelic variation, are co-dominantly inherited, and offer versatility in application, making them ideal for meat traceability.

5.2. Meat Traceability using SNP Profiling

Single Nucleotide Polymorphisms (SNPs) provide another effective method for verifying meat origin. SNPs are single-base variations in DNA sequences, occurring approximately every 100–500 base pairs. Unlike microsatellites, SNPs are biallelic and can be reliably detected using various genotyping technologies.

The process of SNP identification involves selecting SNP markers through nucleotide sequencing, followed by genotyping using methods like direct sequencing, restriction enzyme cutting, single-strand conformation analysis, Tetra-ARMS PCR, or SNP chip technology. These methods offer efficient and accurate SNP detection, contributing to robust meat traceability efforts.

6. Conclusion

Implementing traceability systems is tough but rewarding. It boosts market access by assuring buyers of product quality and disease control. Farmers gain insights for better management and potentially higher income. Starting with voluntary herd-level

systems and utilizing existing resources like veterinary offices is key. Collaboration with processors and slaughterhouses is crucial. A national authority can ensure consistency and support local efforts. Overall, traceability fosters a competitive and sustainable livestock sector, benefiting farmers and the industry as a whole.

****References can be requested from the authors****

Chapter-6

Applications of IT tools for efficient management of animal products value chain

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1. Introduction

India's animal products sector is important to the country's economy, supported by its strong global standing in the production and export of various animal products. India, as the largest milk producer globally, accounted for 24% of the world's total milk production (FAO, 2023). In 2021, India contributed approximately 7.25% to global egg production (FAO, 2023) and supported the largest population of milch animals, including 109.85 million buffaloes, 192.49 million cattle, and 148.88 million goats (20th livestock census, 2019). In the fiscal year 2023-24, India's export of animal products reached Rs. 37,665.51 Crores (USD 4,543.52 million), with buffalo meat being the most significant contributor, comprising Rs. 31,010.10 Crores (USD 3,740.53 million) or over 82% of the total animal products export (DGCIS, 2024). Other key exports included dairy products, poultry products, and natural honey, exported mainly for markets in Malaysia, Vietnam, Egypt, Indonesia, and the UAE. The integration of IT tools for efficient management of this expansive value chain is essential to maintaining and enhancing India's competitiveness in the global market.

The value chain of animal products such as milk, eggs, meat, and leather, plays an important role in ensuring that these products reach consumers safely and efficiently. The management of this value chain involves a series of interconnected steps, from production and processing to distribution and retail. The value chain begins at the production level, where livestock are bred, raised, and maintained. In today's competitive market, where consumer demand for high-quality and safe animal products is increasing, optimizing every link in the value chain is imperative. Efficient management practices not only enhance profitability but also contribute to sustainability by reducing waste and ensuring the ethical treatment of animals.

The evolution of IT in agriculture and animal product management has transformed the industry, enabling real-time data collection, analysis, and decision-making. ICT tools such as web-portal, mobile applications, Geographic Information Systems (GIS), Internet of Things (IoT), data analytics, and blockchain technology have introduced new possibilities for monitoring animal health, optimizing feed production,

enhancing processing efficiency, and ensuring the traceability of animal products from farm to fork. This integration of IT into the value chain has made it possible to achieve greater transparency, sustainability, and responsiveness to consumer demands.

2. IT Tools for Animal Products Value Chain

Information and Communication Technology (ICT) tools have become increasingly vital in the animal production industry, streamlining processes from the management animal to the retail of animal products. These tools encompass a wide range of technologies, including mobile applications, web platforms, data collection and analytics platforms, and automated systems that support farmers in optimizing production, improving animal health, and enhancing overall efficiency. From precision feeding and breeding management to traceability systems that ensure product quality and safety, ICT solutions enable farmers and producers to make data-driven decisions, reduce costs, and meet the growing demand for sustainable and ethical animal products.

2.1. Web platforms

The **National Animal Disease Referral Expert System (NADRES) v2** is an interactive and dynamic web application managed by ICAR-NIVEDI, developed using HTML and PHP for the frontend, and MySQL for the backend. This advanced tool provides early alerts of disease occurrences two months in advance for 13 major livestock diseases across 700 districts in India. NADRES v2 offers comprehensive disease analysis, including state-wise assessments of disease patterns, distribution maps, and the impact of outbreaks on livestock populations. Additionally, it features an Epi Calculator to aid in creating robust sampling plans for disease management. The system's dynamic and automated data visualizations make it an essential resource for effective animal disease prediction and management, significantly enhancing the proactive capabilities of veterinary and livestock management services across the country.

The **e-Gopala**, developed by the National Dairy Development Board (NDDB), is a digital platform designed to assist dairy farmers in enhancing livestock management. It offers features such as Pashu Poshan, which provides guidance on formulating balanced rations to optimize feed costs and productivity; **Ayurvedic Veterinary Medicine**, offering advice on managing common ailments in dairy animals using traditional practices; and **Breeding Services**, which includes information on quality semen, IVF embryos, and sexed sorted semen; **Pashu Bazaar**, a marketplace for buying and selling bovines. Available on both Android and iOS, as well as through a web portal, e-Gopala provides flexible access for users, making it a versatile tool for farmers. With 1,99,398 registered users, the app plays a crucial role in integrating modern technology into traditional farming practices, supporting sustainable and productive dairy farming. **E-Pashu Haat** is a web portal developed by

the Department of Animal Husbandry and Dairying, Government of India, serving as an e-trading market for livestock germplasm and related services. It connects farmers with breeders and agencies, providing real-time access to certified germplasm, including frozen semen and embryos. The portal features a centralized information repository for government use and links to 56 semen stations, 4 Central Herd Registration Schemes (CHRS), and 7 Central Cattle Breeding Farms (CCBF) across multiple states. E-Pashu Haat provides detailed information such as animal/semen IDs, progeny details, rates, terms, and certifications, and provides access to contact information and galleries of various institutes and universities. This platform streamlines the process of acquiring high-quality germplasm and ensures transparency and accessibility in the livestock breeding industry, benefiting 18,01,888 farmers and numerous organizations across India. The **APEDA Meat.Net portal** is an online certification system designed to facilitate the issuance of Health Certificates for meat export consignments from India, as mandated by the country's Export and Import Policy. Each export consignment must undergo compulsory microbiological and other tests by a government lab, accompanied by a Health Certificate. Establishments registered with APEDA are provided with a one-time Username and Password to apply for these certificates online. The application process involves submitting the required documents, such as invoices, packing lists, and test reports, through the portal, followed by a visit to the State Animal Husbandry Office to pay fees and collect the certificate. State Veterinarian officials then log in with their credentials to process and issue the Health Certificate. This streamlined system ensures that meat exports comply with health regulations, supporting the safety and quality of India's meat products in the global market.

2.2. Mobile applications

The **BAIF Godhan Seva app**, developed by Bharatiya Agro Industries Foundation, is designed to enhance livestock management through a focus on Artificial Insemination (AI) services for local and nondescript cattle using imported high milk-yielding bull semen. This app provides a comprehensive platform for efficient cattle management, including farmer registration, cattle registration and identification, AI service management, pregnancy diagnosis follow-up, calving management, semen management, and an appointment diary feature. It supports AI Technicians (AITs) and CDC in-charges (CICs) in managing the lifecycle of livestock progeny and maintaining detailed records for 2 to 20 years. the BAIF Godhan Seva app aids in improving the productivity and sustainability of cattle farming operations. Several mobile applications have been created by ICAR-IVRI, Izatnagar, to provide informational support to a range of stakeholders, including farmers. The **IVRI-Animal** Reproduction (Pashu Prajanan) App is designed to serve as a comprehensive resource for graduating veterinarians, field veterinary officers, and livestock entrepreneurs, offering knowledge on reproductive diseases and disorders in cattle and buffaloes, along with guidance on treatment and control measures. Key

conditions covered include Anestrus, Repeat Breeding, Silent Heat/Silent Estrus, Uterine Torsion, Dystocia, Abortion, Uterine Prolapse, Retention of Fetal Membranes/Placenta, Metritis, Brucellosis, Campylobacteriosis, and IBR-IPV. This app is accessible in 11 languages, including English, Hindi, Punjabi, Bangla, Gujarati, Marathi, Malayalam, Telugu, Tamil, Assamese, and Kannada, and it includes audio support in three languages to aid illiterate users or those who prefer listening. The **IVRI-Dairy Manager App** aims to educate and equip Graduating Veterinarians, Field Veterinary Officers, Developmental Organizations, and Entrepreneurs with skills and knowledge to promote dairy farming. This educational tool covers various aspects of dairy farming, such as breeds, housing, feeding, calf care, general management, clean milk production, and the identification and management of vices in dairy animals. The app also features educational videos on clean milk production and neonatal calf management to enhance the skills of those involved in dairy farming, and it is available in English and Hindi. The **IVRI-Pig Farming App**, developed collaboratively by ICAR-IVRI, ICAR-NRC on Pig, and ICAR-IASRI, aims to provide scientific knowledge and skills to veterinarians, field officers, and entrepreneurs to promote pig farming. The app offers educational content on pig breeds, housing, feeding, breeding, healthcare, and general management, along with tools for economic analysis and project evaluation. The **IVRI-Pig Ration App** assists in formulating balanced rations for swine, utilizing locally available ingredients to meet their nutritional requirements effectively. The **IVRI-Vaccination Guide App** is tailored to impart essential information to veterinarians, field officers, paravets, and livestock, poultry, and pet owners regarding vaccination protocols in domestic animals, poultry, and pets. It includes details on causative agents, vaccine types, serotypes, vaccination schedules, and available commercial vaccines, alongside information about government and private institutions involved in vaccine production in India. The **IVRI Waste Management Guide App** aims to educate veterinarians, field vets, the general public, farmers, and other stakeholders on managing waste from agricultural, livestock, and household sources. It covers composting methods, vermicomposting, biogas production, and newer waste management alternatives such as organic farming, liquid manures, and crop residue management technologies. The app also provides insights into government initiatives and policies related to organic waste management in India. The **IVRI-Disease Control App** is designed to educate stakeholders on significant livestock, poultry, and canine diseases, including symptoms, diagnosis, treatment, prevention, and control measures. It covers bacterial, viral, and parasitic diseases affecting livestock and poultry, along with canine diseases like CD and Rabies. The app also provides details on exotic and emerging diseases, diagnostic laboratories, and government guidelines for disease control in India. This app is available in English and Hindi. The **Parasite Management Guide App** offers information on parasitic diseases in domesticated and wild animals, detailing parasite life cycles, affected organ systems, pathogenesis, diagnosis, and management strategies, including deworming schedules and drug dosages. The **IVRI-Biosecurity and Biosafety App** includes a feature that provides an electronic scoring system,

enabling farm owners to evaluate the current biosecurity level of their farms and implement necessary improvements based on the assessment.

2.3. Data collection platforms

The **Dairy Surveyor** is an advanced data collection platform integrated with the NDDB GIS Web Application, designed to streamline the process of gathering real-time data directly from the field. It allows for the creation and deployment of customized data collection forms, enabling users to capture data on the go with integrated GPS coordinates and on-site photographs. Access to Dairy Surveyor is restricted to authorized users who have been granted permission by the NDDB GIS Application administrator, ensuring secure and controlled use. The platform enhances the accuracy and efficiency of data collection in the dairy sector, significantly contributing to better decision-making and resource management by providing precise and timely information from various dairy operations. The **AMCS Farmer's App**, developed by the National Dairy Development Board (NDDB), is an Automatic Milk Collection System that integrates stakeholders at Union, Federation, and National levels to streamline dairy operations. This app empowers farmers by providing them with instant access to their milk collection data, allowing them to view personal information and historical milk pouring records at any time. It offers real-time updates, sending notifications about milk quantity, quality, and any changes made to their data, thereby enhancing transparency in the dairy sector. Additionally, the app ensures payment transparency by notifying farmers about disbursements and detailing additions, deductions, and price differences. Overall, the AMCS Farmer's App promotes a higher level of accountability and efficiency, helping farmers manage their dairy operations more effectively.

2.4. Advanced technologies and automated systems

Chitale Dairy, founded by B. G. Chitale in 1939 in Pune, is a pioneer in integrating technology into dairy farming. The dairy monitors over 50,000 cows using RFID tags across its satellite farms, providing detailed data on animal health, milk production, nutritional needs, and calving cycles. Centralized data management is achieved through VMware technology and a dedicated server, enabling veterinarians to analyze this data and communicate insights to farmers via SMS daily. Chitale Dairy also offers extensive support and services to farmers, including free veterinary care, high-quality breeding services, and expert advice through call centers and SMS support. Additionally, their "Fields to Farms Program" educates farmers on growing cash crops to reduce dependency on grazing land, and provides free classes on animal husbandry and business management, thus promoting sustainable and profitable farming practices. **Stellapps Technologies**, headquartered in Bangalore and founded in 2011, is a pioneering company focused on digitizing the dairy supply chain in India. It provides end-to-end solutions that enhance efficiency, transparency, and profitability across the dairy sector. Stellapps integrates various aspects of the dairy

supply chain, including herd management, milk production, automated milk collection, and quality assurance through cold storage management. Utilizing a robust technology stack that includes IoT for real-time data collection, Big Data & Analytics for operational optimization and trend prediction, Cloud Computing for centralized data management, and Blockchain for ensuring traceability and transparency, Stellapps empowers over 2.5 million farmers with actionable insights. Different technologies developed by Stellapps are the following:

i. **smartFarms:** A comprehensive app designed to address the agricultural and financial needs of farmers, allowing them to track milk pouring, payments, and purchases efficiently.
ii. **Smartmoo Pay:** Provides rural populations with access to financial products such as loans and insurance, optimizing operational costs for financial service providers in rural India.
iii. **mooON V2:** Monitors essential dairy farm indicators like conception rates, average dry days, open days, herd averages, and more, covering 49 key performance metrics to enhance farm productivity.
iv. **mooON Lite App:** Tailored for farmers with 10 or more cattle, this app focuses on boosting cattle productivity and maximizing herd performance through efficient farm management tools.
v. **mooRetail:** A platform that allows traditional retailers to digitize their business operations seamlessly, promoting broader access to digital retail solutions.
vi. **Stellapps ConTrak:** An IoT-based system for real-time management of the cold chain, enhancing reporting and monitoring of bulk milk coolers, silos, cold rooms, deep freezers, and more, ensuring optimal product quality and traceability.

Case study: mooMark Private Limited, headquartered in Bengaluru, Karnataka, was founded in 2020 with the vision to revolutionize the dairy supply chain through technology-driven solutions by using Stellapps Technologies. Its mission is to support farmers, dairy, and FMCG brands by ensuring traceability and quality at every stage of the milk supply chain. Since its inception, mooMark has expanded from operating in 204 villages to engaging with 65,000 farmers within four years. It boasts a network of over 104,000 registered cattle and facilitates the production and distribution of more than 100,000 liters of milk daily. The mooMark employs various technologies to enhance the dairy supply chain, including mooON, ActiTrak, smartAMCU, smartCC, and ConTrak technology. The Traceability Portal ensures transparency in milk procurement and batch processing, and the Know Your Milk (KYC) service allows customers to trace the milk journey, enhancing consumer confidence. Incorporating advanced technologies like IoT, sensors, and cloud computing, mooMark is at the forefront of transforming the dairy supply chain with innovative and scalable solutions.

2.5. Startups and e-commerce platforms

The **MoooFarm App**, an agritech start-up founded in 2019 by Param Singh, Aashna Singh, Abhijeet Mittal, and Jitesh Arora, provides a comprehensive digital solution for dairy farm management. It offers features like Digital Livestock Management, allowing users to record and maintain cattle lifeline data, manage revenues and expenses, and use predictive analytics for enhanced farm management. The app includes **MoooFarm Saba** for knowledge dissemination, cattle trading, query resolution, and information on loans and subsidies. Users can earn **MoooCoins** by inputting data, which can be redeemed for vouchers, discounts, and rewards. The app also features an **E-commerce platform** for purchasing dairy farming inputs with doorstep delivery, E-Dairy Mitra for connecting with expert veterinarians, and **Fin-Tech services** providing access to credit, cattle insurance, and easy premium options. MoooFarm App aims to empower dairy farmers by integrating technology into their everyday practices, making farm management more efficient and profitable. **Eggoz Nutrition**, founded in 2017 by IIT Kharagpur graduates, is a D2C startup transforming India's egg industry by addressing key issues such as low nutritional value and the use of chemicals in poultry feed. The company ensures antibiotic-free eggs produced with 100% herbal hen feed, resulting in nutritionally superior eggs with bright orange yolks.

The IVRI RABI (RKVY-RAFTAAR Agri Business Incubator) is a flagship incubation program for startups in the animal and veterinary science sectors. Key startups include **Teplu Learning Pvt Ltd**, offering a digital learning platform for dairy farmers, and N**andinandan Breeds & Seeds India Pvt. Ltd.,** which specializes in goat milk products. **Zebu Breeding & Conservation LLP** focuses on improving indigenous cow breeds, while **Magicvets Pvt Ltd** operates a mobile pet clinic. Other notable ventures include **Vet Innovet**, which develops non-invasive anemia diagnosis kits, and **Rudra Agro Live Stock Pvt. Ltd**., providing a blockchain platform for pig farmers. Additionally, startups like **N-Tech Digital Private Ltd**. and **Agverse Technologies Pvt Ltd** are revolutionizing artificial insemination with innovative devices. **Transduceideas Technologies LLP** and **Heeraka Agribiz Pvt. Ltd.** offer telemedicine apps for animal care, while **Medjivan Healthcare Pvt. Ltd.** provides an animal trading platform. These startups, aim to drive significant advancements in animal health, sustainable farming, and efficient livestock and its product management, contributing to the growth and modernization of the agricultural industry.

3. Way forward

A recent focus area has been the merging of Artificial Intelligence (AI) with Information and Communication Technology (ICT) (Gehlot et al., 2022). India has proactively and successfully embraced AI integration across multiple sectors, leading to significant implementations that boost access to public services and optimize operational effectiveness. The **Pig Live Weight (PLW) app** is an intelligent system developed by ICAR-IVRI, for estimating the live weight of pigs using a Convolutional Neural Network (CNN) model. This Android mobile app employs advanced deep

learning techniques, leveraging Keras with TensorFlow as the backend, to provide accurate weight estimations based on image analysis. The experimental analysis of the CNN model demonstrated a high throughput in image-based weight estimation with an R^2 value ranging from 0.734 to 0.801, and the model testing showed an accuracy of 82%. **Artificial Intelligence based Disease Identification System for Animal (AI-DISA)** is an AI-enabled mobile application developed for the automatic identification of livestock diseases using image analysis. Created by ICAR-IASRI in collaboration with 8 State Agricultural Universities and ICAR-IVRI, Izatnagar, the app uses the National Image Base for Livestock Diseases (NIBLD) hosted on the Krishi Megh cloud infrastructure. AI-DISA allows users to capture or upload images of livestock with visible symptoms, and it identifies diseases such as Mastitis, Foot and Mouth Disease in bovines, and Canine Distemper and Parvo Virus in canines. The app provides immediate results along with disease management advisories, enabling farmers and veterinarians to make quick and informed decisions for livestock care. The AI-powered chatbots developed to date include IVRI-Dairy SHRIA, IVRI Sheep & Goat SHRIA, and IVRI Swine SHRIA, each designed to provide specialized support to farmers. **IVRI-Dairy SHRIA**, the Smart Heuristic Response-based Intelligent Assistant, is a collaborative effort by ICAR-IVRI, Izatnagar, and ICAR-IASRI, New Delhi, aimed at addressing queries from dairy farmers through the use of Natural Language Processing (NLP) and machine learning algorithms. This chatbot supports 10 Indian languages and offers speech input and output, making it accessible and user-friendly. It covers a wide range of topics, such as breeding strategies, feeding practices, preventative healthcare, general management, calf-rearing, organic dairy farming, training resources, insurance options, and economic aspects, making it a comprehensive resource for dairy farming. Similarly, **IVRI Sheep & Goat SHRIA** provides extensive information on sheep and goat farming, including breeding, feeding, healthcare, management, kid and lamb rearing, marketing, training, insurance, and economic factors, offering a complete guide for sheep and goat farmers. **IVRI Swine SHRIA** offers in-depth assistance on pig farming, covering breeding techniques, feeding strategies, disease prevention, health management, housing, general farm management, economic planning, biosecurity measures, waste management, and environmental sustainability, providing valuable support to those involved in swine farming.

4. Conclusion

The integration of Information and Communication Technology (ICT) tools into the animal products value chain in India has significantly transformed the industry, enhancing efficiency, transparency, and sustainability. The use of web platforms, mobile applications, data collection platforms, and advanced technologies like Artificial Intelligence (AI) has empowered stakeholders across the value chain from farmers to exporters with real-time data, improved decision-making capabilities, and robust traceability systems. This digital transformation not only optimizes

production and processing but also ensures the safety and quality of animal products, which is crucial for maintaining India's competitive edge in the global market. These innovations are poised to drive even greater improvements in the management of the animal products value chain, contributing to the overall growth and modernization of India's agricultural industry.

****References can be requested from the authors****

Chapter-7

Creating Entrepreneurship Opportunities through Innovative Processing of Heritage and Ethnic Meat Products

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1. Introduction

The global food industry has recently witnessed a growing interest in ethnic cuisines, driven by an increasing desire for diverse and authentic culinary experiences. Ethnic meat products, ranging from traditional curries and cured meats to exotic cuts and specialty preparations, reflect unique culinary traditions and present promising opportunities for entrepreneurs. The growing globalization of food culture and the rising demand for authentic and diverse meat products underscore the relevance of exploring entrepreneurship in this field. This article suggests the path for entrepreneurs interested in ethnic meat products. It also addresses the challenges and risks associated with this market.

2. Ethnic meat products of India

India's ethnic meat products show a vast spectrum of flavours and cooking techniques that reflect the country's diverse culinary heritage. From kebabs and tandoori meats to rich curries and unique regional dishes, these traditional meats are integral to India's food culture. Each product carries its history and significance, offering a glimpse into the diverse and vibrant culinary traditions of India. These products often incorporate unique spices, cooking methods, and preparation techniques, making them integral to the country's gastronomic landscape. Below is an overview of some notable traditional meat products from various regions of India:

2.1. Kebabs and Tandoori Meats

A. Shaami Kebab

Shaami Kabab is quite popular in the states of Uttar Pradesh and Hyderabad. These are minced meat patties made from mutton, chevon, carabeef or lamb mixed with chana dal, condiments and spices. They are typically shallow-fried and are known for their spicy and aromatic flavour.

B. Seekh Kebab

Seekh Kabab is quite popular in the Northern parts of India. It is made from minced meat (often mutton, chevon, or carabeef) mixed with spices, condiments and herbs. The mixture is skewered and cooked over charcoals or in a tandoor (clay oven), giving it a smoky flavour.

C. Tandoori Chicken

Tandoori chicken has originated from Punjab. A dressed chicken is marinated in a mixture of yoghurt and spices (such as turmeric, cumin, coriander, and garam masala) and then cooked in a tandoor. It is known for its vibrant red colour and smoky flavour.

2.2. Curries and Stews

A. Rogan Josh

It is quite popular in the UT of Jammu and Kashmir and is considered as a signature dish of Kashmiri cuisine. Rogan Josh is a slow-cooked lamb curry made with yoghurt, garlic, ginger, and a blend of spices including Kashmiri red chilli which gives it a rich red colour.

B. Mutton Korma

It is quite popular in North India. It is a creamy and mildly spiced curry made with yoghurt, cream, and a blend of spices. It often includes nuts and raisins adding to its rich flavour.

C. Chettinad Chicken Curry

Its origin is from Tamil Nadu and is a staple in Chettinad cuisine. It is known for its spicy flavour. It is made with a variety of spices including star anise, fennel seeds, and black pepper.

2.3. Dried and Preserved Meats

A. Bresaola

It is a traditional beef product that is seasoned, air-dried, and aged and is famous in Goa. It is often served thinly sliced and can be used in various dishes or as a snack.

B. Salami

Traditionally it is not Indian but is very famous in various regions including Kerala. It is produced in some regions, especially among the Christian communities. It involves curing and fermenting meat with spices.

2.4. Specialty Meats and Delicacies

A. Nihari

Quite famous in Delhi and Uttar Pradesh. It is a slow-cooked stew made with carabeef or chevon and is traditionally eaten as a breakfast dish along with naan or paratha.

B. Biryani

Several variants of biryani such as chicken, mutton, chevon or carabeef are available in the market and are consumed throughout India. In the most popular variant, marinated raw meat is layered with partially cooked rice.

2.5. Regional and Tribal Meat Dishes

A. Bamboo Shoot Curry

Quite popular in Northeast India (such as Assam and Nagaland). Bamboo shoots are used in curries with pork or beef, giving the dish a unique flavour. The curry is usually spicy and aromatic.

2.6. Unique Regional Preparations

A. Vindaloo

Originally a Portuguese dish adapted to Goan cuisine, vindaloo is a spicy, tangy pork curry made with vinegar, garlic, and a blend of spices.

B. Bhuna Ghost

Popular in North India. A dry curry where meat is cooked with a rich blend of spices until it is well-coated and the flavours are concentrated.

C. Mutton Galouti Kabab

Originating from Lucknow, it is known for its soft texture. These are made from finely minced mutton mixed with spices and papaya pulp and cooked in a thick bottom pan.

D. Wazwan

A variety of traditional meat products, collectively known as 'Wazwan', are prepared in Jammu and Kashmir and served during festivals, marriages and other ceremonies. The wazwan generally constitutes 15 flavourful ready-to-eat meat products (out of a total of 36 dishes) which are freshly prepared and served hot as a part of a splendid meal. Preparation of most of the products of wazwan is a specialized culinary practice mostly restricted to a limited category of people called "Waza".

3. Popularization of ethnic meat products

There are several ways for popularization of ethnic meat products and has been a fascinating trend. Here's a brief overview of how this trend has developed:

i. **Globalization and Cultural Exchange**: As people from different cultures interact more frequently, there's a growing curiosity about diverse cuisines. Several ethnic meat products have gained popularity beyond their regions of origin. This cross-cultural exchange has been facilitated by immigration, travel, and media.

ii. **Food Media and Social Media**: Television shows, cooking channels, and social media platforms have played a significant role in introducing and popularizing ethnic meat products. Chefs and food influencers often showcase unique dishes, making them more accessible and appealing to a global audience.

iii. **Fusion Cuisine**: The blending of different culinary traditions has led to the creation of fusion dishes that incorporate ethnic meat products into new and innovative recipes.

iv. **Health and Sustainability Trends**: Some ethnic meat products are being embraced for their perceived health benefits or sustainable practices. For instance, traditional methods of preparing meat, such as slow cooking or

fermentation, are sometimes seen as healthier or eco-friendly compared to industrialized meat production.

v. **Ethnic Restaurants and Food Trucks**: The rise of ethnic restaurants and food trucks has made ethnic meat products more accessible. These establishments often introduce local communities to traditional dishes and flavours that might not have been previously available.

vi. **Culinary Tourism**: Traveling to experience authentic local cuisine has become more popular. As travellers seek out unique food experiences, they contribute to the growing demand for ethnic meat products in their home countries.

vii. **Gourmet and Specialty Stores**: Ethnic meat products are increasingly available in gourmet and specialty grocery stores. These stores often cater to adventurous eaters and food enthusiasts looking to explore new culinary experiences.

Overall, the popularization of ethnic meat products reflects a broader trend of cultural exploration and appreciation, driven by curiosity, media influence, and changing food landscapes.

4. Skills for processing ethnic meat products

Processing of ethnic meat products encompasses a range of techniques used to transform raw meat into products that are safe, flavourful, and have a longer shelf life. It often requires specialized skills that are integral to preserving the authenticity and quality of the dishes. Some key skills and processing techniques used for the production of ethnic meat products are:

4.1. Understanding Traditional Methods

- **Marinating**: Many ethnic meat products rely on marinating techniques to infuse flavours. Understanding the right balance of ingredients and timing is crucial.
- **Drying and Curing**: Techniques such as drying or curing are common in several ethnic products. These methods require precise control of temperature and humidity. In curing, the use of salt, nitrates, or nitrites is made to preserve meat and enhance flavour. Curing may be either dry curing (rubbing with salt and spices) or wet curing (soaking in the brine solution)**.**
- **Smoking**: It imparts a characteristic smoky flavour to ethnic meat products. It may be of two types -

i. **Cold Smoking:** Smoking at lower temperatures (below 90 °F or 32 °C) for flavouring and preserving without cooking.

ii. **Hot Smoking:** Smoking at higher temperatures (above 140 °F or 60 °C) that cooks the meat and imparts a smoky flavour.

- **Fermentation -** Adding beneficial bacteria to meat to develop flavour and preserve it. Common in products such as salami and pepperoni.

4.2. Knife Skills and Butchery

- **Butchering**: Proficiency in butchering is essential for cutting meat into the appropriate sizes and shapes for different ethnic dishes.
- **Knife Skills**: Mastery of knife skills ensures precise cutting which is important for dishes requiring specific textures or presentations.

4.3. Spice Blending and Flavour Balancing

- **Spice Blending**: Many ethnic meat products involve unique spice blends. For instance, the wazwan products of J&K require a huge amount of spices such as cumin, aniseed, red chilli, javitri, saffron, cardamom, coriander, pepper and cinnamon. Knowing how to blend spices to achieve the desired flavour profile is crucial.
- **Flavour Balancing**: Adjusting the balance of salt, sourness, and sweetness in the product is key to authentic flavour profiles.

4.4. Fermentation and Preservation

- **Fermentation**: Some ethnic meat products use fermentation to develop unique flavours. This requires knowledge of fermentation processes and safe handling practices.
- **Preservation Techniques**: Techniques such as smoking, curing, and pickling are used to preserve meat and enhance flavours.

4.5. Cooking Techniques

- **Grilling and Roasting**: Mastery of grilling techniques is important for some traditional dishes and may involve controlling grill temperature and cooking times.
- **Braising**: In techniques such as braising meat is slowly cooked with a small amount of liquid. These methods require careful attention to cooking times and temperatures.
- **Searing:** Cooking meat quickly at high temperatures to create a flavourful crust. Searing is often used to create flavour and colour, rather than fully cooking the meat.

4.6. Cultural Knowledge and Authenticity

- **Cultural Sensitivity**: Understanding the cultural significance and traditional methods behind ethnic meat products helps in preserving authenticity.

4.7. Food Safety and Hygiene

- **Handling and Storage**: Proper meat handling and storage practices are essential to prevent contamination and spoilage. This includes maintaining proper temperatures and using hygienic techniques.

- **Knowledge of Regulations**: Familiarity with food safety regulations and standards for meat processing including temperature controls and sanitary practices is important for ensuring product safety.

4.8. Use of specialized technical equipment

- **Equipment**: Using equipment such as meat grinders, sausage stuffers, or smokers requires technical know-how. Mastery of these tools is essential for producing high-quality ethnic meat products.

4.9. Packaging

- **Vacuum Sealing:** Removing air from packaging to extend shelf life and prevent freezer burn.
- **Modified Atmosphere Packaging (MAP):** Replacing air in the packaging with gases such as nitrogen or carbon dioxide to preserve freshness.

4.10. Emulsifying/pounding – During the preparation of some ethnic meat products e.g. rista and goshtaba, meat is beaten with a wooden hammer and fat is incorporated to make a stable emulsion. Such techniques provide a unique texture to the product.

Each of the above-mentioned techniques can be combined in various ways to produce different types of ethnic meat products.

5. Points to be considered for creating entrepreneurship in the area of ethnic meat products

Combining entrepreneurship with heritage or ethnic meat products can create a unique niche in the market. This requires:

5.1. Market Research and Feasibility Study

- **Identify Target Markets**: Research should be carried out to know which communities or demographics are most interested in ethnic or heritage meat products.
- **Competitive Analysis**: A survey should be conducted to analyse existing businesses in the area and to understand their strengths and weaknesses.

5.2. Product Development

• **Authenticity**: Ensure that the products stay true to their heritage or ethnic origins. This might involve working with experts or communities knowledgeable about traditional processing techniques.

• **Innovation**: Introduce modern twists to traditional recipes or processing methods to appeal to contemporary tastes and preferences. This could include healthier processing methods or new packaging technologies.

5.3. Branding and Positioning

• **Unique Selling Proposition (USP)**: Highlight what makes your products unique. This could be the authenticity of the ingredients, traditional methods, or ethical sourcing.

• **Storytelling**: Use storytelling to connect with customers. Share the heritage, culture, and history behind the meat products to create a strong emotional appeal.

5.4. Supply Chain and Production

• **Sourcing Ingredients**: Establish relationships with reliable suppliers of traditional ingredients.

• **Processing**: Consider innovative processing techniques that enhance flavour, preserve heritage, and ensure quality.

5.5. Marketing and Sales Channels

• **Online Presence**: Develop a strong online presence through a website and social media. Consider e-commerce platforms to reach a larger population.

• **Local Markets**: Partner with local farmers' markets, specialty stores, or ethnic grocery stores to reach customers interested in heritage products.

5.6. Regulatory Compliance

- **Food Safety**: Ensure compliance with food safety regulations and standards which can vary from region to region.
- **Labelling**: Properly label your products to reflect their heritage and any relevant certifications or claims.

5.7. Community Engagement and Partnerships

- **Collaborate with Heritage Groups**: Work with cultural organizations or heritage groups to ensure authenticity and gain support.
- **Educational Workshops**: Offer workshops or demonstrations to educate consumers about the heritage and production processes.

5.8. Feedback and Adaptation

- **Customer Feedback**: Gather feedback from customers to continuously improve your products.
- **Adaptation**: Be prepared to adapt your business model based on market trends and consumer preferences.

  This approach can help you build a brand that respects tradition while appealing to modern consumers.

6. Steps to start a business of ethnic meat products

Starting a business specializing in ethnic meat products involves several key steps, from planning and regulatory compliance to production and marketing. The step-by-step process includes:

1. Conduct Market Research
2. Develop a Business Plan
3. Legal and Regulatory Compliance
4. Secure Funding
5. Establish a Supply Chain
6. Develop and Test Products
7. Build Your Brand
8. Launch and Promote
9. Monitor and Adjust
10. Scale and Expand

7. Innovations and Future Trends in the Ethnic Meat Market

The ethnic meat market, a niche yet growing sector within the broader meat industry, is witnessing dynamic changes driven by innovations and emerging trends. These developments are reshaping how ethnic meat products are produced, marketed, and consumed. It includes:

7.1. Technological Advancements in Production

A. Precision Meat Production

Precision meat production involves the use of advanced technologies to enhance the efficiency and quality of meat production. Innovations such as 3D printing and cultured meat are gaining attention:

- **3D Printing:** This technology allows for the creation of meat products with intricate textures, designs and flavours. Ethnic meat products can benefit from 3D printing by replicating traditional textures and shapes with high precision. This can lead to new product offerings that closely resemble traditional ethnic meats but are produced using more sustainable methods.
- **Cultured Meat:** Also known as lab-grown or *in vitro* meat, this innovation involves cultivating muscle cells in a bioreactor in a laboratory. For ethnic meat producers, cultured meat offers a way to produce traditional meats without the ethical and environmental concerns associated with conventional livestock farming.

B. Blockchain for Supply Chain Transparency

Blockchain technology is being increasingly adopted to enhance transparency and traceability in the meat supply chain necessary to develop the confidence of customers. Blockchain can provide detailed information about the origin and journey of meat products, ensuring that they meet authenticity claims and quality standards.

Transparent supply chains build consumer trust. Knowing that their ethnic meat products are ethically sourced and produced can be a significant selling point for consumers.

C. Automation and Robotics

Automation and robotics are revolutionizing meat processing and production. Automated systems can streamline processes, such as cutting, marinating, and packaging, allowing for greater consistency and scalability in production. Robotics can enable more personalized and custom-made ethnic meat products, catering to specific consumer preferences and dietary requirements.

7.2. Ethical Sourcing and Animal Welfare

Ethical sourcing and improved animal welfare practices are becoming more important. There is a growing demand for meat products from animals raised under humane conditions. Ethnic meat producers are increasingly adopting practices that ensure better living conditions for livestock.

7.3. Consumer Trends and Preferences

There is a trend towards enhancing the nutritional profile of ethnic meats. This includes fortifying products with additional vitamins, minerals, and beneficial fats, or using leaner cuts of meat. Ethnic meat products are being developed with added health benefits, such as probiotics or omega-3 fatty acids, catering to the growing interest in functional foods.

7.4. Digital and Direct-to-Consumer Strategies

- **Use of E-Commerce and Online Platforms**

The rise of e-commerce has opened new avenues for ethnic meat producers. Ethnic meat producers are increasingly using online platforms to reach consumers directly. This allows for greater control over branding and customer relationships.

- **Use of Social Media and Influencer Marketing**

Social media plays a crucial role in promoting ethnic meat products. Collaborations with food influencers and chefs can enhance brand visibility and credibility. Social media platforms are used to engage with consumers, educate them about the cultural significance of ethnic meats, and share behind-the-scenes content about production processes.

7.5. Expansion into New Markets and Market Penetration

Opportunities for ethnic meat producers should be explored in the new and emerging markets. Adapting ethnic meat products to local tastes and preferences can help penetrate new markets. This involves modifying recipes or offering localized versions of traditional products.

8. Contribution of ethnic meat products to job creation and local economies

Ethnic meat products contribute significantly to local economies and job creation by supporting local agriculture, generating employment, and fostering economic development. They enhance food systems, drive tourism and cultural events, and provide export opportunities. By promoting local businesses and preserving cultural heritage, ethnic meats play a vital role in stimulating economic activity and enriching communities.

8.1. Support for local agriculture and food production

Ethnic meat products contribute to job creation and local economies in various ways. Ethnic meat products often rely on locally sourced ingredients for their production. This creates demand for local farmers and suppliers, boosting the agricultural sector. The processing and production of ethnic meats add value to raw agricultural products.

8.2. Job Creation

The production of ethnic meat products creates jobs in various sectors including processing plants, meat packing facilities, and quality control. Ethnic meat products often require specialized distribution and retail networks. This creates additional employment opportunities in areas such as distribution centres, specialty stores, and ethnic markets.

- **Economic Development and Diversification**

The presence of ethnic meat products can stimulate the growth of local businesses including specialized meat shops, restaurants, and food festivals. This diversification contributes to the overall economic development of a community.

- **Tourism and Hospitality**:

Ethnic meat products can attract tourists interested in experiencing local cuisine. This drives economic activity in the hospitality sector including hotels, restaurants, and local attractions.

- **Cultural and Food Festivals**:

Events celebrating ethnic foods including meat products can attract visitors and stimulate local spending. Festivals and markets that feature ethnic meat products often boost local economies by drawing crowds and promoting regional culture.

8.3. Cultural and Social Benefits

- **Preservation of Traditions**:

The production and consumption of ethnic meats help preserve cultural traditions and culinary practices. This cultural preservation contributes to community pride and cultural diversity.

- **Community Engagement**:

Ethnic meat products often involve community participation and engagement. Local producers and businesses frequently collaborate with community groups to promote and celebrate cultural heritage.

8.4. Export Opportunities

Ethnic meat products that are exported contribute to local economies through foreign exchange earnings. Successful export ventures can boost the profile of local producers and enhance regional economic growth.

8.5. Supporting Small and Medium Enterprises (SMEs)

The ethnic meat sector often includes small and medium enterprises (SMEs) that drive innovation and entrepreneurship. These businesses can foster local economic growth and create employment opportunities. Ethnic meat products can inspire local start-ups and businesses to enter niche markets, contributing to economic dynamism and diversification.

9. Obstacles to entering the ethnic meat market

Entering the ethnic meat market involves overcoming a range of obstacles related to regulatory compliance, supply chain logistics, cultural preferences, and economic factors. Businesses need to carefully navigate these challenges by investing in market research, understanding local regulations, and developing robust supply chain and marketing strategies. Addressing these obstacles effectively can pave the way for successful market entry and growth in the ethnic meat sector. Entering the ethnic meat market can be a lucrative opportunity but it comes with its own set of challenges and obstacles such as:

- Ethnic meat products may have stringent health and safety regulations including specific requirements for processing, handling, and labelling. Navigating these regulations can be complex and requires thorough knowledge of local standards.
- Ethnic meat products often need specific certifications, such as halal or organic, depending on the target market. Obtaining these certifications can be time-consuming and costly.
- Maintaining the required temperature conditions throughout the supply chain is crucial for meat products. Effective cold chain management can be challenging, particularly when supplying the products to regions with less developed infrastructure.
- Coordinating the transportation and distribution of ethnic meats involves managing multiple supply chain elements including handling, packaging, and timely delivery. Logistics can become particularly complex when dealing with specialty products.
- In some markets, consumers may be unfamiliar with certain ethnic meats. Educating consumers about the product's authenticity, benefits, and preparation can require significant marketing efforts.

- The initial investment required for market entry including compliance costs, production setup, and marketing can be substantial. Smaller businesses might find it challenging to bear these costs.
- Ensuring consistent quality across different batches and markets is crucial. Variability in quality can impact consumer trust and brand reputation.
- Building brand recognition in new markets can take time and resources. Establishing a strong brand presence and differentiating from competitors is crucial for success.

10. Conclusions

The ethnic meat market is undergoing significant transformations driven by technological advancements, sustainability efforts, changing consumer preferences, and global expansion. Innovations such as precision meat production, blockchain for supply chain transparency, and alternatives are shaping the future of this sector. By embracing these trends and leveraging new technologies, entrepreneurs can capitalize on emerging opportunities and navigate the evolving landscape of the ethnic meat market.

****References can be requested from the authors****

Chapter-8

Innovations in pork processing technologies for livelihood security

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1. Introduction

Pig population in NE states is around 40% and Assam is ranked top in pig production in the country. More than 95% of indigenous people of NER are meat eaters and pork is considered as a principal meat among the different kinds of meat. Pig is considered as an animal of choice because of natural attraction of our local tribal people towards the avocation of pig rearing. In fact pig is considered as a prized animal and consumption of pork is the highest in NER. Of late pork products are also becoming popular and varieties of pork products are being imported to the region to satisfy the palate of our local people.

Meat processing scenario of our country is awfully underdeveloped. More than one percent of the total production of meat is converted into processed meat. Thus, considering the effect of globalization and free marketing concept of WTO, there is tremendous scope of meat processing in our country. Otherwise some other countries will occupy and fulfill the present need with their products at a cheaper rate. This will cause big harm both for the producers and the farmers as well. Therefore, India should take all possible steps to develop the meat processing sector on priority basis.

2. Meat/pork processing

Pork processing refers to any treatment which brings about substantial physical and chemical changes in the natural state of pork. In broadest sense this includes grinding, curing, smoking cooking, canning freezing, fermentation, dehydration, production of intermediate moisture products and use of certain additives such as seasoning, chemicals and enzymes etc. In processing, properties of fresh meat have been modified, however, the inherent property of "being meat" must remain intact even after processing.

3. Meat technology

It is the practice of any or all of the applied science that have practical values or industrial use. It is the application of all scientific or modern knowledge for the production of meat in easier methods which include slaughter, processing, transportation, storage and marketing etc. in such a way that has some practical value over traditional way of production. Thus, processing is a part of meat technology.

4. Advantages of meat processing

i. To change the form or characteristics of the products so as to make it easier to market and more attractive to the consumers
ii. Facilitates in incorporation of non-meat ingredients for quality and economy

iii. Helps in preservation, transportation and distribution to cover larger population (City life becomes easier)
iv. Helps in utilization of low quality meat and by-products
v. Development of different products with different recipe, thus varieties of value added and functional pork products can be produced
vi. Helps in fast food chain of food industries
vii. Inhibit climatic factors and destroy microorganisms that might cause deteriorative changes or spoilage
viii. Improves nutritive values

5. Requirements for pork processing

For successful processing of pork following infrastructures are required.

- Constant flow of healthy pigs to feed the plant
- Scientific transportation of live animals
- Slaughter house with lairage and modern slaughter equipments
- Modern processing equipments
- Pork products to be developed with good recipe
- Scientific packaging, cold storage and marketing facilities
- By-products utilization facilities
- Technical manpower

6.Basic methods of pork processing

Comminution: It is a process by which raw meat is subdivided or reduced into small pieces, chunks, chips or slices etc.Such particle size reduction helps in the uniform distribution of seasoning, enhance the tenderness of meat of old animals and reduces the fuel cost for cooking .Comminution is done with the help of meat mincer and bowl chopper is also used for making fine emulsion. e.g. Sausage. Non-comminuted meat products are-ham, bacon, corned beef etc.

Emulsion: It is a process where two immiscible liquids are mixed together and one of which is dispersed in the form of small droplets or globules in the other liquid .Thus, emulsion has two phases- a continuous phase and a dispersed or discontinuous phase. These phases remain immiscible due to the existence of an interfacial tension between them .To stabilize the meat emulsion, emulsifying agents are used. Meat emulsion is an oil-in-water emulsion.

Blending/preblending: Blending refers to an additional mixing, i.e. mixing of certain chemicals or other products in comminuted meat prior to further processing .e.g.- curing, and seasoning .

***Meat* extension:** A variety of non-meat food items are incorporated into products which are commonly referred as extenders, binders and fillers. Reasons of incorporation:-

- To improve emulsion stability
- To improve water binding capacity.
- To enhance flavours
- To reduce shrinkage during cooking.
- To improve slicing characteristics

- To reduce formulation cost.

E.g. Fillers - Soy products, potato, starch

Extenders – Wheat, rice, pea, corn flours etc.

Binders – Milk powers, dried whey and sodium casinate

Seasoning: Any ingredient that is added to improve or modify the flavours of process meat products. In addition to flavours, seasonings also help to preservation of meat. Seasonings include salt, spices, herbs, vegetable, sweeteners monosodium glutamate, e.g.-Anise, clove, cinnamon, cumin, garlic, ginger and onion etc.

Use of humectants: Various additives employed for lowering the water activity of foods are know as humectants e.g. glycerol, propylene glycol, sorbitol sugars.

Use of preservatives: Any substance which is capable of inhibiting, retarding or arresting the process of fermentation, acidification or other deterioration of food and enhances the shelf life of the food products is known as preservative. Two classes of preservatives are there.

Class I: - Common salt, sugar, honey, glucose, dextrose, spices, vinegar and edible oils etc. No restriction on the quantity is there.

Class II:- Permitted within specified limits in specified food and levels must be declared. E.g. Benzoic acid, nitrates, nitrites and ascorbic acid etc.

Use of antioxidants: Delays or retards or prevents fat oxidation. e.g. BHT (Butylated hydroxyl toluene), BHA (Butylated hydroxyl anisole), Vit.C, and Vit. E

Common processing technology for preparation of value added pork products

Drying: The purpose of drying is to reduce the availability of moisture. It also reduces the water activity of the food products and thus, hinders the growth and multiplication microbes. Rehydration is required before consumption. Used mainly for military purposes. It is not a usual method for preparation of value added pork products.

Salting and curing: High concentration of salt expel out the water by osmosis, thus, microbial growth is restricted. Another purpose is colour and flavour retention. Main disadvantage is that halophilic bacteria may grow. Salting and curing is a part of processing of some of the value added pork products.

Smoking: Smokes contains formaldehyde, phenol, alcohol, cresol, aliphatic compounds, aldehyde and ketone which have bacteriostatic effect. Smoke is mainly effective against vegetative cells. It also coagulates the surface protein and blocks the entry of microorganisms. Liquid smoke is better. Certain carcinogenic and mutagenic substances like Heterocyclic amines (HCA) and polycyclic aromatic hydrocarbon (PAHs). Smoking enhances the flavour and acceptability of the pork products.

Canning: It is a thermal processing method. Processed products are packed in hermitically sealed containers and then treated with heat (At least 121^0C). Cans are then cooled and stored. Can meats are ready to eat products.

Enrobed pork products: Coating of meat products with edible materials in the form of batter using flours, whole egg and other cereal products is done to produce enrobed pork products. Enrobing imparts the product a crispy texture, increases eating quality.E.g. Pork cutlets, pork patties and nuggets etc.

Intermediate moisture pork products: Pork products with 15-50% moisture content with moderate juiciness and texture, inhibit growth of bacteria, moulds and yeast, water activity between 0.6 to 0.85, self stable at ambient temperature for a considerable length of time are known as intermediate moisture pork products. A mixture of sodium chloride, glycerin, lactic acid and antioxidants are used in the formulations.

Restructured pork products: It is a process where pre cut or comminuted meat is moulded into a shape resembling to a natural streak or intact cut. It is a good method of upgrading value of low quality meat. The pre cut meat pieces are tumbled or massaged and because of this process, protein exudes from the meat surface and thereafter high pressure is exerted to give a restructured new product.

Fermented pork products: Fermented pork products can be prepared by using lactic acid producing specific microflora like Lactobacillus, Micrococcus and Pediococcus etc. The bacterial cultures create such an environment that other spoilage and harmful microorganisms can not grow. Based on the moisture contents, three types of fermented pork products can be manufactured, E.g. Dry, semi-dry and moist. Extension of storage life, safety of foods and improvement of sensory properties are the benefits.

Heat processing (Cooking): Cooking must be done at an internal temperature of not below 65-70^{0}C. There are few changes taken place during cooking. There is coagulation and denaturation of protein, connective tissue (Collagen) conversion into gelatin, increasing of tenderness, and development of brown colour and textural changes of meat tissue. Generally meat and meat products are cooked by three methods.

- Dry heat cooking:- Dry heat cooking involves either broiling, roasting or frying. This method is suitable for pork of low connective tissue like pork shoulder, loin cured ham etc.
- Moist heat cooking:- This method is recommended for relatively tough cuts with large amount of connective tissue. Pressure cooking, simmering, stewing and braising are the example of moist heat cooking
- Microwave cooking:- It is a modern and rapid method. The heating results from the conversion of microwave energy to heat by friction from internal molecular rotation caused by the interaction of molecules with the rapidly fluctuating electromagnetic field. This method is many times faster than conventional method.

Designer pork products: Pork can be effectively utilized to produce designer/health pork products. This is achieved by lowering fat, sodium and calories by incorporating fat replaces, fibers and natural antioxidants. A combination of hydrocolloid fat substitute, sodium alginate and carrageenan enhance the sensory attributes of low fat meat products. It is now tried to formulate designer meat food with bioactive peptides so as to use as disease preventing and health promoting food.

7. Formulation of processed pork products

There are hundreds of processed pork products in the world. Some of the very common processed pork products are ham, bacon, salami, sausages, luncheon meat, pickles, patties, loaves, balls, nuggets, slices and pork snack products.

- The first goal of formulation of the product should be such that it maintains uniform appearance, taste, composition, nutritive value, physical properties. The product should be acceptable to the consumers.
- The second goal is that it must meet the quality standards.
- The third goal is that the proportion of meat ingredients like meat, fat and by-products to non meat ingredients like binders, extenders, fillers, spices salt etc. should be such that the products become stable and cost effective.

8. Innovations in pork processing technologies

Advances in these technologies not only improve the efficiency and safety of pork production but also have broader socio-economic impacts.

8.1. Advanced Processing Equipment

- **Automated Processing Lines**: Modern automated systems increase efficiency by reducing manual labor and processing time. These systems handle tasks such as deboning, grinding, and packaging with high precision, leading to reduced waste and increased product consistency.
- **High-Pressure Processing (HPP)**: HPP technology involves applying high pressure to meat products, which enhances safety by eliminating pathogens without the need for preservatives. This method extends shelf life and improves food safety, which is crucial for market access and consumer trust.
- **Smart Sensors and IoT**: Integration of smart sensors and Internet of Things (IoT) technologies enables real-time monitoring of processing conditions such as temperature, humidity, and contamination levels. These innovations help maintain optimal processing environments and ensure product quality and safety.

8.2. Sustainable Processing Practices

- **Energy Efficiency**: New technologies focus on reducing energy consumption in pork processing plants. Innovations such as energy-efficient refrigeration systems and waste heat recovery systems contribute to lower operational costs and reduced environmental impact.
- **Waste Management**: Advances in waste management, including the development of bio-digesters and composting systems, help in converting pork by-products into valuable resources like biogas and organic fertilizers. This not only reduces waste but also generates additional income streams.
- **Water Recycling**: Technologies that enable the recycling of water used in processing operations minimize water consumption and reduce environmental pollution. Closed-loop water systems help in managing resources more sustainably.

8.3. Food Safety and Quality Control

- **Blockchain Technology**: Blockchain provides a transparent and immutable record of the pork supply chain from farm to table. This technology enhances traceability, helping to quickly identify and address any issues related to food safety or quality.

- **Advanced Hygiene Protocols**: Innovations in cleaning and sanitation protocols, such as automated cleaning systems and antimicrobial coatings, improve hygiene standards in processing facilities. These measures reduce the risk of contamination and ensure higher quality products.
- **Rapid Testing Methods**: New rapid testing technologies for pathogens and contaminants enable faster and more accurate detection, ensuring that only safe and high-quality pork products reach consumers.

8.4. Economic and Social Impacts

- **Increased Efficiency and Reduced Costs**: By adopting advanced processing technologies, pork producers can lower production costs and increase profitability. This financial stability supports the livelihoods of farmers and workers in the pork industry.
- **Market Expansion**: Enhanced product quality and safety standards enable access to new markets and export opportunities. This market expansion can lead to higher incomes and improved economic security for communities reliant on pork production.
- **Skill Development**: The adoption of new technologies requires training and skill development for workers, which can lead to job creation and improved employment opportunities in rural areas.

8.5. Challenges and Considerations

- **Cost of Implementation**: While advanced technologies offer significant benefits, the initial investment can be substantial. Financial support and subsidies may be necessary to help small and medium-sized enterprises adopt these innovations.
- **Technical Expertise**: The successful implementation of new technologies requires skilled personnel. Investing in education and training programs is essential to build a knowledgeable workforce capable of managing and maintaining advanced processing systems.
- **Infrastructure Limitations**: In some regions, inadequate infrastructure may hinder the effective adoption of new technologies. Addressing infrastructure challenges is critical for ensuring widespread benefits.

9. Conclusion

Innovations in pork processing technologies significantly enhance livelihood security by improving efficiency, safety, and sustainability in pork production. While challenges exist, the benefits of these advancements—such as increased income opportunities, better food safety, and reduced environmental impact—underscore their importance in supporting the livelihoods of those involved in the pork industry. Continued investment in and support for these technologies can drive further progress and ensure long-term benefits for communities reliant on pork production.

****References can be requested from the authors****

Chapter-9

Packaging and Marketing Strategies Required to Boost Processed Meat Sector

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1. Introduction

Packaging is a fundamental component of both production and physical distribution, serving as a crucial link in the supply chain that ensures products reach consumers in optimal condition. Central to its role are the three Ps of packaging: protection, preservation, and promotion. These principles guide the design and functionality of packaging, ensuring that products are shielded from damage, maintain their quality over time, and are presented attractively to consumers. In recent years, the packaging industry has undergone significant transformation, especially within the burgeoning food sector. As the food industry evolves, packaging has adapted to meet new demands, taking on multiple roles that go beyond its traditional functions. Today's packaging must balance a variety of requirements, including safety, functionality, convenience, attractiveness, cost-effectiveness, and environmental friendliness. Consumers and manufacturers alike are increasingly focused on extending the shelf-life of food products, enhancing tamper-evidence, and providing clearer labeling. At the same time, there is a strong push for "greener" packaging solutions that minimize environmental impact. This growing emphasis on eco-friendly packaging reflects a broader societal shift towards sustainability, driving innovation in materials and design to meet both consumer expectations and environmental standards.

2. Functions of Packaging

Packaging plays a vital role in a product's lifecycle, ensuring its journey from production to consumption is smooth and effective. These functions can be classified into several key areas:

2.1. Protection: Packaging offers essential physical protection, shielding products from damage during transportation, handling, and storage. It guards against physical impacts, moisture, temperature fluctuations, and contaminants. Tamper-evident packaging also ensures consumers that the product has not been compromised, safeguarding its safety and integrity.

2.2. Preservation: Packaging extends the shelf life of products, particularly in food and pharmaceuticals, by preventing spoilage and degradation. Barrier materials protect against gases, moisture, and light, helping to maintain the product's quality over time.

2.3. Promotion: Packaging promotes brand identity by incorporating logos, colors, and graphics that reflect the brand's values and image. Visually appealing designs and informative labels also attract consumers, influencing their purchasing decisions.

2.4. Information: Labeling on packaging provides essential details about the product, such as ingredients, usage instructions, nutritional information, and expiration dates. It also ensures regulatory compliance by meeting industry-specific legal standards.

2.5. Convenience: Packaging is designed for ease of use, featuring user-friendly elements like easy-pour spouts, resealable closures, and portion controls. It also facilitates efficient storage, handling, and transportation, optimizing shelf space and reducing waste.

2.6. Sustainability: Sustainable packaging aims to minimize environmental impact by using recyclable, biodegradable, or compostable materials. It focuses on resource efficiency in the production process, reducing the ecological footprint.

2.7. Security: Packaging ensures product integrity by keeping it secure throughout its lifecycle, from manufacturing to point-of-sale. This security builds consumer trust by guaranteeing product authenticity and safety.
These functions highlight the essential balance that packaging must achieve, addressing practical needs while meeting consumer expectations and regulatory standards.

3. Factors affecting growth of packaging industry in INDIA

The growth of the packaging industry in India is driven by various factors, including economic, technological, and social elements. Economic growth, with rising disposable incomes and rapid urbanization, increases demand for packaged goods. The expansion of the retail sector, particularly through organized retail and e-commerce, fuels the need for sophisticated packaging, especially for convenience and ready-to-eat foods. Technological advancements in materials and automation improve packaging efficiency and sustainability, while regulatory changes ensure safety and environmental standards are met. Consumer trends, such as health awareness and preferences for eco-friendly packaging, also play a crucial role. Improvements in supply chain logistics, particularly in cold chain infrastructure, enhance packaging effectiveness for perishable goods. Globalization offers export opportunities, and exposure to global best practices drives innovation in the Indian market. Additionally, investments in research and development and the rise of

entrepreneurial ventures foster innovation and competition. Environmental concerns push companies to adopt sustainable packaging solutions, driven by consumer advocacy for greener options. Cultural factors, including traditional packaging preferences, influence product development tailored to local markets. Together, these factors contribute to the dynamic growth and evolution of India's packaging industry.

4. Packaging of Food Products

The packaging of food products is undergoing a significant transformation as the industry seeks to address the environmental challenges associated with traditional plastic packaging. The push towards biodegradable packaging represents a crucial step in this evolution, aiming to mitigate the issues related to plastic wastes, which are multifaceted, complex, and compounding.

4.1. Biodegradable Packaging and Its Challenges

Biodegradable packaging is designed to break down naturally over time, reducing the environmental impact compared to conventional plastics. However, its implementation faces several challenges. The treatment of plastic waste involves complex processes, including collection, sorting, and recycling, which are often hindered by contamination and inefficiencies. Additionally, ensuring that biodegradable materials decompose effectively requires specific conditions, which are not always met in typical waste management systems. Despite these challenges, biodegradable packaging must also meet high standards for appearance and performance. It should be clean, bright, and visually appealing to enhance the product's marketability, while also maintaining functional integrity. Packaging must be robust enough to protect and preserve food, meeting stringent standards such as ISO and ASTM. This includes ensuring it is steam-proof, waterproof, temperature-resistant, and has low permeability to vapor and gas, which is crucial for maintaining food quality. The functional requirements for biodegradable food packaging are demanding. It must withstand various conditions during storage and transportation, including exposure to steam and moisture, and perform well under different temperatures. For example, microwavable packaging must remain safe for use without releasing harmful substances or compromising the food’s safety. The journey toward environmentally friendly and consumer-friendly packaging has begun, with ongoing innovations and improvements in materials and processes. The industry is increasingly focused on finding solutions that balance environmental sustainability with practical functionality, striving to create packaging that is both effective and sustainable. As demand for environmentally responsible packaging grows, it is essential for the industry to continue addressing these challenges while adhering to performance standards. This will ensure that biodegradable packaging not only helps reduce plastic waste but also meets the practical needs of food safety and consumer appeal.

4.2. Edible Coatings and Modified Atmosphere Packaging (MAP): Innovations and Trends

The integration of edible coatings with Modified Atmosphere Packaging (MAP) represents a significant advancement in food packaging technology. This combination enhances preservation and functionality, addressing both food quality and environmental concerns. Edible coatings are thin layers applied directly to food products, serving various purposes. These coatings effectively limit gas exchange and moisture transmission between the food and its environment, which helps maintain freshness and extend shelf life. By acting as barriers against oxygen, carbon dioxide, and moisture, they reduce spoilage and deterioration. Beyond their barrier properties, edible coatings offer additional benefits. They can act as antioxidants, preventing oxidative damage to the food. They also possess antimicrobial properties, inhibiting the growth of harmful microorganisms, thereby enhancing food safety. Furthermore, these coatings can incorporate flavor components, enriching the sensory experience of the food. MAP is a rapidly growing technology in the food packaging sector, designed to extend the shelf life of perishable products by altering the atmospheric composition within the package. Typically, MAP uses gases such as oxygen (O_2), carbon dioxide (CO_2), and nitrogen (N_2) to create an environment that slows spoilage processes and preserves product quality. When combined with edible coatings, MAP can significantly reduce overall packaging costs. This dual approach allows for more efficient resource use, potentially decreasing the need for additional preservatives and packaging materials.

The evolving market demands transparency and flexibility in food packaging materials. Consumers and manufacturers are increasingly seeking packaging solutions that are not only functional but also align with sustainability goals. As a result, there is growing interest in transparent, flexible packaging materials that offer product visibility while maintaining protective qualities. Additionally, there is a trend toward developing edible MAP barrier materials. These materials hold promise for enhancing the sustainability of food packaging by reducing waste and supporting eco-friendly practices. The demand for such materials reflects a broader shift toward more sustainable and consumer-friendly packaging solutions.

4.3. Active Packaging and Absorbers: Enhancing Food Preservation and Quality

Active packaging is an innovative approach to food preservation, transcending traditional passive methods by actively modifying the internal environment of the package. This technology plays a vital role in extending the shelf life of packaged foods, improving their safety, and enhancing sensory qualities such as taste, texture, and aroma. By incorporating various absorbers, active packaging systems help manage the conditions within the package, ensuring the quality of the food during storage and transport. The packaging systems interact directly with the food contents, offering several key benefits. These systems control the internal atmosphere, slowing spoilage and degradation, inhibit the growth of harmful microorganisms, reducing

the risk of foodborne illnesses and by managing factors such as odor and flavor, active packaging maintains or improves the food's sensory qualities.

4.3.1. Types of Absorbers in Active Packaging

i. **Oxygen Absorbers**: Remove oxygen to prevent oxidative spoilage and maintain freshness in products like meats and snacks.
ii. **Carbon Dioxide Absorbers**: Absorb excess CO_2, preventing spoilage in products like fresh produce and baked goods.
iii. **Ethylene Absorbers**: Capture ethylene gas, slowing the ripening of fruits and vegetables to extend freshness.
iv. **Moisture Absorbers**: Control humidity to prevent mold growth in dry foods and snacks.
v. **Off-Flavour Absorbers**: Neutralize unwanted odors and flavors that may develop during storage.
vi. **UV Light Absorbers**: Block UV light, protecting sensitive ingredients like vitamins and fats from degradation.
vii. **Lactose and Cholesterol Absorbers**: Remove lactose or cholesterol, catering to dietary needs and health-conscious consumers.

In addition to absorbers, active packaging systems may also include releasers or emitters, which introduce beneficial substances to further enhance food quality and safety. These systems help maintain sensory attributes and prolong the shelf life of food products.

4.3.2. Types of Releasers/Emitters

i. **Carbon Dioxide Emitters**: Release CO_2 to create a modified atmosphere that inhibits microbial growth.
ii. **Ethanol Emitters**: Emit ethanol vapors, which act as antimicrobial agents to reduce bacteria and fungi growth.
iii. **Antimicrobial Preservatives Releasers**: Release antimicrobial compounds that prevent the growth of harmful microorganisms.
iv. **Sulphur Dioxide Releasers**: Release SO_2 to preserve dried fruits and wines by preventing microbial growth and oxidative spoilage.
v. **Antioxidant Releasers**: Emit antioxidants to prevent oxidative damage, particularly in high-fat foods.
vi. **Flavouring Emitters**: Release flavor compounds to enhance the taste and aroma of packaged foods.

Releasers and emitters help keep food fresh for longer by managing the package's internal conditions. They reduce the risk of microbial contamination and spoilage. Flavouring emitters and antioxidants maintain or improve the taste and smell of foods. Customizable emitters offer tailored solutions for different food products, addressing their specific preservation needs.

4.4. Intelligent Packaging: Monitoring and Information Systems

Active packaging often includes sensors and indicators that monitor the condition of the food, providing valuable information about potential spoilage or compromised integrity during transport and storage. Intelligent packaging, which includes time-temperature indicators (TTIs), is a cutting-edge technology designed to monitor and respond to the conditions experienced by packaged products. This technology is especially crucial in maintaining the quality and safety of perishable goods, ensuring that they are stored and transported under optimal conditions.

Time-Temperature Indicators (TTIs): TTIs are devices integrated into packaging that provide real-time information about the time-temperature exposure of the product. They are essential for ensuring that sensitive items, such as food and pharmaceuticals, are kept within safe temperature ranges throughout their lifecycle. TTIs help in identifying exposure to both high and low temperatures, which could compromise product quality. The operation of TTIs can be based on several principles:

i. **Mechanical**: These indicators use physical changes, such as color shifts or movement, in response to temperature changes. They often rely on materials that undergo a visible transformation when exposed to certain temperatures.
ii. **Chemical**: Chemical-based TTIs involve reactions that change color or release gases when exposed to specific temperatures over time. These indicators are often used for their simplicity and cost-effectiveness.
iii. **Electrochemical (RFID)**: Radio Frequency Identification (RFID) TTIs use electronic sensors and microchips to monitor and record temperature conditions. These systems provide precise, digital data and can be integrated with broader tracking and data systems.
iv. **Enzymatic**: Enzymatic TTIs utilize enzymes that react to temperature changes, causing a visible change in the indicator. These are often used in food packaging to monitor conditions that could affect food safety.
v. **Microbiological**: Microbiological TTIs use microorganisms that change their activity in response to temperature. These indicators are particularly useful for monitoring conditions in products that are sensitive to microbial contamination.

TTIs (Time-Temperature Indicators) can be categorized based on their response characteristics into three main types:

a) **Critical Temperature Indicators (CTI)**: These indicators are designed to signal whether a product has been exposed to temperatures exceeding a specific critical threshold. A clear indication is given if the product experiences conditions that could compromise its quality or safety. CTIs are commonly used in industries like pharmaceuticals and sensitive food products where exceeding a certain temperature can be harmful.
b) **Critical Temperature/Time Regulator Integrators (CTTI)**: CTTIs combine both temperature and time factors to offer a cumulative assessment of exposure. They evaluate whether the product has been subjected to damaging conditions by integrating the effects of both time and temperature. These indicators are

particularly useful for products like vaccines and perishable foods, where both factors are crucial for maintaining safety and efficacy.

c) **Continuous, Temperature-Dependent Response TTIs**: These indicators provide a continuous record of temperature exposure over the product's entire lifecycle. By offering detailed information on temperature fluctuations and durations, they enable more precise monitoring. This type of TTI is ideal for applications requiring detailed temperature histories, such as complex supply chains or high-value products that demand stringent control.

5. Packaging Requirements under the Food Safety and Standards (Packaging and Labelling) Regulations, 2011

The Food Safety and Standards (Packaging and Labelling) Regulations, 2011, established by the Food Safety and Standards Authority of India (FSSAI), provide comprehensive guidelines to ensure the safety, quality, and transparency of packaged food products. These regulations are designed to protect consumer interests and ensure that packaged foods meet the necessary safety and quality standards. Key Requirements of the Regulations are as below:

5.1. Labeling Requirements

- **Product Name**: The label must clearly state the name of the food product.
- **Ingredient List**: All ingredients used in the product must be listed in descending order of their weight or volume.
- **Nutritional Information**: Labels must include nutritional information such as energy value, fat, protein, carbohydrates, and other relevant nutrients.
- **Date of Manufacturing and Expiry**: The label must specify the date of manufacturing and the expiry or best-before date to ensure product freshness.
- **Batch or Code Number**: This is essential for tracking and tracing the product in case of quality issues or recalls.
- **Name and Address of Manufacturer**: Information about the manufacturer or distributor must be provided.
- **Country of Origin**: The country where the product is manufactured must be indicated, especially for imported goods.
- **Storage Instructions**: If applicable, the label should provide specific storage instructions to maintain product quality.
- **Allergen Information**: Potential allergens contained in the product must be clearly indicated to inform consumers with allergies.

Packaging materials must be safe for use with food products and must not transfer harmful substances to the food. It must be clean and hygienic, protecting the food from contamination. Also should include tamper-evident features to ensure that the product has not been altered or compromised and packaging should ideally be recyclable or biodegradable, aligning with environmental sustainability goals. Certain products may have specific size and shape standards to ensure uniformity and ease of handling. Labels must be in the official language(s) of the country, with mandatory information in local languages to ensure that all consumers can understand the product details. Any health claims or warnings on the label must be substantiated and comply with regulatory guidelines to prevent misleading information. Packaging and labeling must comply with both national and international standards where applicable, ensuring consistency in global markets.

5.2. Enforcement and Compliance: Regulatory authorities conduct regular inspections and monitoring to ensure compliance with packaging and labeling

requirements. Non-compliance can result in penalties, recalls, or other enforcement actions. Manufacturers may need to obtain certification or approvals from relevant authorities to ensure that their packaging and labeling practices meet the required standards. The Food Safety and Standards (Packaging and Labelling) Regulations, 2011 lays out the specific packaging requirements for different types of food products to ensure safety, prevent contamination, and provide clear information for consumers such as Packaging requirements for Milk and Milk Products, for Edible Oil/Fat. for Fruits and Vegetables Products, for Canned Meat Products, for Drinking Water (Both Packaged and Mineral Water) etc. Under the Food Safety and Standards (Packaging and Labelling) Regulations, 2011, specific labeling requirements for pre-packaged foods are outlined to ensure transparency and provide consumers with vital information about the product. A health claim of 'trans fat free' can be made if the trans fat content in the product is less than 0.2 grams per serving. Similarly, the claim 'saturated fat free' may be used when the saturated fat content is less than 0.1 grams per 100 grams or 100 milliliters of the product.

6. Strategies Required To Boost Processed Meat Sector

Boosting the processed meat sector through effective packaging and marketing strategies requires a multi-faceted approach that addresses consumer preferences, industry trends, and regulatory concerns. Some of the strategies to consider:

6.1. Innovative Packaging: Use eco-friendly, biodegradable, or recyclable packaging materials to appeal to environmentally conscious consumers and highlight the sustainability aspect on the packaging. Design packaging that enhances convenience, such as resealable packs, easy-to-open designs, and portion-controlled sizes. This appeals to busy consumers looking for quick and easy meal solutions. Invest in attractive and modern packaging designs that stand out on the shelves. Use clear labeling and vibrant colors that catch the consumer's eye and communicate the product's quality. Include windows in the packaging to allow consumers to see the product, building trust by showing the quality of the meat. Also, provide detailed ingredient lists and nutritional information to address consumer health concerns. Incorporate QR codes or NFC technology that provide additional product information, recipes, or brand stories. This can enhance the customer experience and engagement.

6.2. Marketing Strategies: With increasing health consciousness, market processed meat products as healthier options by emphasizing high protein content, low-fat options, and the absence of artificial additives. Highlight any certifications, like organic or non-GMO, on the packaging. Create a compelling brand story that connects with consumers on an emotional level. Emphasize the quality of the meat, the sourcing of ingredients, and the brand's commitment to ethical and sustainable practices. Use digital marketing platforms to target specific consumer segments, such as fitness

enthusiasts, busy professionals, or families. Leverage social media, influencers, and content marketing to build brand awareness and loyalty. Offer promotions, discounts, and loyalty programs to encourage repeat purchases. Collaborate with retailers for in-store promotions, and utilize seasonal marketing campaigns around holidays or special events. Introduce unique product variations like organic, grass-fed, or specialty-flavored meats to differentiate from competitors. Highlight these differentiators in marketing campaigns and on packaging. Collaborate with restaurants, food delivery services, or meal kit companies to introduce your processed meat products to new audiences. Co-branding and cross-promotions can also help reach a wider market. Develop engaging content, such as recipe ideas, cooking tips, and behind-the-scenes videos, to educate and inspire consumers. Utilize platforms like YouTube, Instagram, and Pinterest to share this content.

6.3. Adapting to Market Trends: Try to address consumer demand for healthier processed meats by reducing sodium, fat, and preservatives. Promote products that align with dietary trends, such as keto, paleo, or plant-based alternatives. With growing consumer awareness of sustainability and ethical concerns, market your products as responsibly sourced, with animal welfare certifications and reduced carbon footprints. Tailor products and marketing campaigns to local tastes and preferences, particularly in regions with strong cultural ties to specific types of meat products.

6.4. Regulatory Compliance and Safety Assurance: Ensure compliance with local and international food safety standards. Highlight this on packaging to reassure consumers of the product's safety and quality. Clearly communicate the origin of the meat and any traceability measures taken to ensure high standards. This builds trust with consumers, especially in regions where food safety is a significant concern.

Regularly gather and analyze consumer feedback to understand preferences and areas for improvement. Use this data to refine products, packaging, and marketing strategies. Stay ahead of consumer trends by continually innovating and expanding your product line. Introduce new flavors, cuts, and processing techniques that align with evolving consumer tastes. By implementing these strategies, companies in the processed meat sector can boost their market presence, attract new customers, and retain existing ones, ultimately driving growth and profitability in the industry.

****References can be requested from the authors****

Chapter-10

Utilization of unconventional feed resources for economical meat animal production

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1. Introduction

India's livestock sector, recognized as one of the largest in the world, plays a pivotal role in the nation's economy, particularly in rural areas where millions of farmers rely on animal husbandry for their livelihood. The country is a leading producer of both meat and dairy products, catering not only to its vast domestic market but also to the growing global demand for animal-based food products. Despite this, the sustainability of meat production in India is increasingly threatened by a critical shortage of conventional feed resources. This scarcity is largely due to the decline in the availability of common grazing lands and the increasing shift towards the cultivation of commercial crops, which prioritize higher economic returns over traditional fodder crops. As a result, the conventional feed resources such as crop residues, greens, and concentrates that are essential for livestock sustenance are becoming progressively harder to obtain.

The livestock sector in India is currently facing a green fodder shortage of approximately 63.5 percent and a dry fodder shortage of 23.5 percent. These shortages are expected to worsen, with projections indicating that the deficit could increase to 66 percent for green fodder and 25 percent for dry fodder by 2030 (Jitendra, 2017). This impending crisis poses a significant challenge to the economic viability of meat production, not only in India but also in other developing countries where similar trends are observed. The high cost and limited availability of conventional feed resources are driving up the cost of meat production, making it increasingly difficult for small-scale farmers to compete in the market.

In response to these challenges, there has been growing interest in the exploration and utilization of unconventional feed resources. These resources, which include agricultural by-products, leguminous seeds, shrubs, and various novel plant species, offer a viable alternative to traditional feeds. Unconventional feed resources are particularly advantageous in regions where conventional feedstuffs are scarce, expensive, or environmentally unsustainable. They provide an opportunity to utilize

materials that are often considered waste, thereby reducing the environmental impact associated with their disposal and contributing to a more sustainable livestock production system.

Agricultural by-products, for example, are generated in large quantities during the processing of crops and other agricultural products. These by-products, which include fruit and vegetable peels, seed husks, and crop residues, are often rich in nutrients and can be processed into animal feed. In addition, leguminous seeds and certain shrubs have been found to possess high protein content and other beneficial properties, making them suitable as alternative feed resources. The utilization of these unconventional feed resources not only helps in reducing the reliance on traditional feeds but also contributes to the reduction of feed costs, which is a significant factor in the overall cost of meat production.

Moreover, the use of unconventional feed resources aligns with the principles of the circular economy, where waste materials are repurposed into valuable inputs for production processes. This approach not only helps in addressing the feed shortage but also plays a crucial role in mitigating environmental pollution. The effective processing and utilization of these resources can help reduce the carbon footprint associated with meat production, as well as decrease the environmental burden caused by the disposal of agricultural by-products.

This chapter delves into the exploration of unconventional feed resources, highlighting their potential to address the growing challenges in the livestock industry, particularly in the context of feed scarcity and rising production costs. By examining the types of agricultural and agro-industrial by-products that can be repurposed as livestock feed, this chapter emphasizes the nutritional value these resources offer and the various processing methods that enhance their efficacy. It also discusses the economic and environmental benefits of integrating these unconventional feeds into meat production systems, thereby contributing to more sustainable and cost-effective practices. Through a comprehensive analysis, this chapter aims to provide insights into how the strategic use of unconventional feed resources can not only sustain but also improve the quality of meat animal production, making it a viable solution for the future of livestock farming.

2. Types of Unconventional Feed Resources

Agricultural Wastes Agricultural wastes are byproducts left after the harvesting, processing, or production of raw agricultural products. These include crop residues like straw, husks, and stalks, as well as byproducts from the fruit, vegetable, and cereal processing industries. For instance, apple pomace, a byproduct of apple juice production, and citrus pulp from juice extraction are examples of agricultural wastes that can be utilized as livestock feed.

Agricultural wastes are rich in fiber and other nutrients, making them suitable for ruminant diets. They can be fed directly to livestock or processed through methods

such as ensiling or pelleting to enhance their nutritional value and palatability. The utilization of these byproducts not only provides an economical feed source but also addresses environmental concerns related to waste disposal.

Agro-industrial byproducts are residues generated from the processing of agricultural products in industries such as sugar, oilseed, and fruit and vegetable processing. Examples include sugarcane bagasse, spent grain from breweries, and oilseed cakes from the oil extraction process (Table 1). These byproducts are often rich in energy, protein, and fiber, making them valuable components of livestock rations. Sugarcane bagasse, for example, is a fibrous byproduct of sugar extraction that can be used as a roughage source in ruminant diets. Similarly, oilseed cakes, such as those from soybean, groundnut, or mustard, are high in protein and can be incorporated into livestock feed to improve the nutritional quality of the diet.

Table 1: Percentage of wastes generated from different fruits and vegetable processing[7].

Sr.No.	Fruits/vegetables	Residues	Percentage of wastes
1.	Apple	Peel, pomace, seed	25
2.	Mango	Peel, stones	45
3.	Citrus	Peel, rag, seed	50
4.	Tomato	Skin, core, seed	20
5.	Pineapple	Skin, core	33
6.	Grape	Stem, skin, seed	20
7.	Guava	Peel, core, seed	10
8.	Potato	Peel	15
9.	Onion	Outer leaves	10
10.	Banana	Peel	35
11.	Pea	shell	40

3. Nutritional Value and Processing of Unconventional Feed Resources

The nutritional composition of unconventional feed resources varies widely depending on the type of material and the processing method used. These feeds can provide essential nutrients such as protein, energy, fiber, vitamins, and minerals. However, some agricultural and agro-industrial byproducts may contain anti-nutritional factors or toxic compounds that need to be neutralized before feeding to livestock. Common methods for processing unconventional feed resources include:
Ensiling: This method involves fermenting the feed material in an anaerobic environment, which enhances its preservation and nutritional value. Ensiling is particularly useful for high-moisture materials like fruit and vegetable byproducts.

Pelleting: Pelleting improves the handling, storage, and feed efficiency of unconventional feeds. It also reduces the bulkiness of fibrous materials, making them easier to transport and store.
Chemical Treatment: Chemical treatments, such as ammoniation or alkali treatment, can improve the digestibility of fibrous residues by breaking down complex carbohydrates and neutralizing anti-nutritional factors.
Fermentation: Biological treatments like fermentation can enhance the nutritional quality of agro-industrial byproducts by increasing protein content and reducing anti-nutritional factors.

4. Examples of Unconventional Feed Resources

Apple Pomace: Apple pomace, the residue left after juice extraction, is rich in fiber, vitamins, and minerals. It can be ensiled or dried and incorporated into livestock diets as a source of energy and nutrients. Studies have shown that apple pomace can be included in the diets of ruminants, poultry, and pigs without adverse effects on growth performance or health (Bhushan et al., 2008; Shalini & Gupta, 2010).
Citrus Pulp: Citrus pulp, a byproduct of the citrus juice industry, is high in soluble sugars and pectin, making it an excellent energy source for ruminants. It can replace a significant portion of traditional feed ingredients like maize or barley in ruminant diets, contributing to cost savings and sustainable production (Wadhwa & Bakshi, 2013).
Brewers' Spent Grain (BSG): BSG is the residue left after the extraction of wort in the brewing industry. It is high in fiber and protein and can be used as a feed ingredient for ruminants, pigs, and poultry. The inclusion of BSG in livestock diets has been shown to improve growth performance and reduce feeding costs (Mladenović et al., 2019).
Sugarcane Bagasse: Sugarcane bagasse, the fibrous residue from sugar extraction, is a valuable roughage source for ruminants. Although it is low in protein, its fiber content makes it suitable for inclusion in the diets of cattle and sheep, particularly in regions where conventional roughages are scarce (Maneerat et al., 2015).

5. Role of Agricultural By-products

Agricultural by-products constitute a major category of unconventional feed resources. These include crop residues, processing by-products, and waste products from food industries. Common examples are brans, husks, and oilseed cakes. These by-products are not only abundant and inexpensive but also rich in nutrients that can support the dietary needs of meat animals. For instance, wheat bran and rice bran are high in energy and moderate in protein, making them suitable substitutes for more expensive cereal grains in animal diets. Similarly, oilseed cakes such as those from soybeans, groundnuts, and sunflowers are excellent protein sources that can replace costly commercial feeds. The studies have shown that the inclusion of agricultural by-

products in livestock diets can maintain or even improve growth performance and meat quality. For example, the use of apple pomace, a by-product of the fruit juice industry, has been demonstrated to enhance the antioxidant capacity of meat, leading to improved shelf life and nutritional value. The fibrous content of these by-products also contributes to better digestion and nutrient absorption in ruminants, thereby enhancing overall animal health and productivity (Vasta et al., 2008).

Legume Seeds as Alternative Protein Sources: Legume seeds such as peas, chickpeas, and faba beans have been recognized as valuable alternative protein sources in meat animal production. These seeds are not only rich in protein but also contain essential amino acids that are critical for muscle development in meat animals. Moreover, legumes are capable of fixing atmospheric nitrogen, which enriches soil fertility and reduces the need for synthetic fertilizers in agricultural systems. Inclusion of legume seeds in animal diets has been associated with several benefits, including improved fatty acid profiles in meat. For instance, animals fed with legume-based diets tend to produce meat with higher levels of conjugated linoleic acid (CLA) and omega-3 fatty acids, which are known for their health benefits. Additionally, these diets have been reported to improve meat's organoleptic properties, such as tenderness and juiciness, making the meat more palatable and acceptable to consumers (Vasta et al., 2008).

Drought-Tolerant Shrubs: Sustaining Meat Production in Arid Regions: In arid and semi-arid regions, where conventional fodder crops are difficult to cultivate, drought-tolerant shrubs like saltbush and cactus have emerged as vital feed resources. These shrubs are not only resilient to harsh climatic conditions but also offer nutritional benefits that can enhance the quality of meat produced in these regions. For example, cactus cladodes have been shown to increase the levels of beneficial fatty acids in the meat of small ruminants. Additionally, the high vitamin E content in saltbush helps in stabilizing meat color by protecting myoglobin from oxidation. These properties make drought-tolerant shrubs a viable alternative for sustaining meat production in challenging environments while improving the nutritional quality of the meat (Vasta et al., 2008).

As source of antioxidants: Utilizing unconventional feed resources not only addresses the nutritional needs of livestock but also contributes significantly to enhancing the antioxidant status of the diet. Agro-wastes like apple pomace (AP) has been identified as rich sources of bioactive compounds, particularly antioxidants. These by-products are often discarded despite their high nutritive value, including energy-rich carbohydrates and natural polyphenolic compounds such as chlorogenic acid, catechins, and phloridzin. When processed through controlled self-fermentation, these agro-wastes can be transformed into antioxidant-enriched feed resources. The fermentation process enhances the antioxidant properties of these feed resources by breaking down the cellular structures, releasing existing antioxidants, and potentially synthesizing new bioactive compounds. Studies have shown that combining energy-rich AP with protein-rich SMC and fermenting them improves their nutritional quality, resulting in a product that not only serves as a sustainable maize replacer but also contributes to the reduction of oxidative stress in animals. This dual benefit of

improved nutritional content and enhanced antioxidant capacity makes these unconventional feed resources as a valuable addition to livestock diets, promoting better health and performance while simultaneously reducing environmental waste (Jairath et al., 2023).

Economic and Environmental Benefits: The adoption of unconventional feed resources presents significant economic and environmental advantages for the livestock industry. By repurposing agricultural and agro-industrial byproducts as animal feed, producers can substantially reduce their reliance on costly conventional feedstuffs, leading to lower production costs. This practice not only alleviates the financial burden on farmers but also addresses the environmental challenges associated with waste disposal, such as landfill use and pollution. For example, integrating fruit and vegetable byproducts into animal diets provides a sustainable and cost-effective feed source, while simultaneously mitigating the environmental impact of waste decomposition and the resulting greenhouse gas emissions. Moreover, the use of drought-resistant plants and other non-traditional feed resources ensures a consistent supply of feed, particularly in regions where conventional feed availability is limited. This approach supports the principles of a circular economy by transforming waste into valuable resources, thus enhancing the sustainability and resilience of the livestock sector.

6. Challenges and Future Directions

While the use of unconventional feed resources presents numerous benefits, several challenges must be addressed to fully realize their potential. These include variability in the nutritional quality of these feeds, the presence of anti-nutritional factors, and the need for appropriate processing technologies. Additionally, there is a need for further research to optimize the inclusion levels of these byproducts in livestock diets and to assess their long-term effects on animal health and productivity. Future research should focus on the development of efficient processing methods to enhance the nutritional value of unconventional feeds and reduce the presence of anti-nutritional factors. Moreover, the adoption of these feeds on a larger scale will require education and awareness among livestock producers about the benefits and proper use of unconventional feed resources.

7. Conclusion

The utilization of unconventional feed resources offers a promising solution to the challenges of feed scarcity and high production costs in the livestock sector. By incorporating agricultural and agro-industrial byproducts into livestock diets, producers can achieve more sustainable and economical meat production while reducing the environmental impact of waste disposal. As research and technology continue to advance, the potential for these unconventional feeds to contribute to the sustainability and profitability of the livestock industry will only increase.

Chapter-11

Innovations and Entrepreneurship Opportunities in Processing of Milk and Milk Products

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1. Introduction

The dairy industry has long been a cornerstone of agricultural economies, providing essential nutrition and a variety of products consumed globally. However, as consumer preferences evolve and technological advancements accelerate, the dairy sector faces both challenges and opportunities. Innovations in milk processing and the burgeoning field of entrepreneurship in this domain promise to reshape the industry, making it more efficient, sustainable, and aligned with modern consumer demands. This article explores the latest innovations in milk processing, examines emerging entrepreneurial opportunities, and discusses the potential impacts on the dairy industry.

2. Technological Innovations in Milk Processing

2.1. High-Pressure Processing (HPP)

High-Pressure Processing (HPP) is a non-thermal pasteurization technique that enhances food safety and extends shelf life while preserving the nutritional quality and taste of milk. By subjecting milk to high pressure, typically ranging from 300 to 600 MPa, harmful pathogens are inactivated without the need for heat. This method retains more of the natural flavors and nutrients, addressing consumer demand for minimally processed and natural products. Entrepreneurs in the dairy sector can explore HPP as a means to differentiate their products and cater to health-conscious consumers.

2.2. Ultrafiltration and Membrane Technologies

Ultrafiltration and other membrane technologies have revolutionized milk processing by enabling the separation of milk components at a molecular level. These techniques allow for the production of concentrated milk proteins, lactose-free products, and the efficient removal of contaminants. Ultrafiltration can also be used to create whey protein isolates and other value-added products. This technology opens opportunities for entrepreneurs to develop niche products with higher protein content or specific dietary benefits, catering to fitness enthusiasts and individuals with lactose intolerance.

2.3. Smart Dairy Processing Systems

The integration of Internet of Things (IoT) and artificial intelligence (AI) into dairy processing systems represents a significant leap forward. Smart sensors and automated systems can monitor and control various aspects of milk processing, including temperature, pH levels, and microbial content, in real-time. These innovations lead to improved consistency, quality control, and operational efficiency. Entrepreneurs can leverage these technologies to establish data-driven dairy operations that enhance product quality and streamline production processes.

3. Sustainable Practices and Eco-Friendly Innovations

3.1. Green Energy Solutions

Sustainability is a growing concern in the dairy industry, and innovations in green energy solutions are helping address environmental impacts. Solar panels, biogas production from dairy waste, and energy-efficient machinery are becoming increasingly prevalent. By adopting renewable energy sources and optimizing energy usage, dairy processors can reduce their carbon footprint and operational costs. Entrepreneurs can explore opportunities in developing or integrating green technologies into their operations to attract environmentally conscious consumers.

3.2. Waste Minimization and By-Product Utilization

Efficient waste management and by-product utilization are critical for sustainable dairy processing. Innovations such as converting dairy waste into biodegradable plastics, animal feed, or compost are gaining traction. Additionally, the development of value-added products from by-products, such as lactose-free dairy alternatives or specialty cheeses, offers new revenue streams. Entrepreneurs can capitalize on these opportunities by creating businesses focused on waste reduction and the utilization of dairy by-products.

4. Product Innovation and Market Expansion

4.1. Functional and Health-Boosting Dairy Products

Consumer interest in functional foods is driving innovation in dairy products with added health benefits. Probiotics, omega-3 fatty acids, and vitamins are being incorporated into milk and dairy products to enhance their nutritional profiles. Innovations in this area include probiotic yogurts, fortified milk, and dairy-based supplements. Entrepreneurs can tap into this trend by developing new products that cater to health-conscious consumers seeking added nutritional value in their dairy consumption.

4.2. Plant-Based and Hybrid Dairy Alternatives

The rise of plant-based diets has led to an increase in demand for dairy alternatives made from soy, almond, oat, and other plant sources. Hybrid products that combine

traditional dairy with plant-based ingredients are also emerging. These innovations cater to a diverse range of dietary preferences and offer opportunities for entrepreneurs to enter new market segments. Developing high-quality, palatable plant-based or hybrid dairy products can attract both vegan and flexitarian consumers.

5. Entrepreneurship Opportunities in Dairy Processing

5.1. Niche Markets and Specialty Products

Entrepreneurs can explore opportunities in niche markets by focusing on specialty dairy products. Artisan cheeses, organic milk, and ethnic dairy products that cater to specific cultural preferences are examples of niche areas with growth potential. By offering unique and high-quality products, new entrants can establish themselves in specialized segments of the dairy market.

5.2. Direct-to-Consumer Models

The direct-to-consumer (DTC) model has gained popularity across various industries, including dairy. By leveraging e-commerce platforms and subscription services, dairy entrepreneurs can reach consumers directly, offering fresh, personalized, and convenient product options. This model allows for better customer engagement, brand loyalty, and control over product quality and distribution.

5.3. Agri-Tech and Digital Innovations

The intersection of agriculture and technology presents numerous entrepreneurial opportunities. Innovations in precision agriculture, data analytics, and digital platforms for managing dairy farms can enhance productivity and profitability. Entrepreneurs can explore opportunities in developing or adopting agri-tech solutions that optimize dairy farming practices, from breeding and feed management to herd health monitoring.

6. Conclusion

The dairy industry is undergoing a transformative phase driven by technological advancements, sustainability concerns, and evolving consumer preferences. Innovations in milk processing, eco-friendly practices, and product development are creating new entrepreneurial opportunities in this sector. By embracing these innovations and addressing market demands, entrepreneurs can contribute to the growth and modernization of the dairy industry, fostering a more sustainable and consumer-focused future.

****References can be requested from the authors****

Chapter-12

Processing Technologies for Development of RTE Shelf-Stable Meat Products

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1. Introduction

In today's first paced world, ready-to-eat (RTE) shelf-stable meat products have emerged as convenient and reliable dietary options. From canned meats and jerky to pouched meals and cured sausages, the variety of RTE shelf-stable meat products available today caters to diverse tastes and dietary preferences. These meat products are designed to be consumed straight from the package, requiring no additional cooking or processing. This makes them ideal for astronauts, military persons, busy individuals, outdoor enthusiasts, and in emerging situations with limited access to raw materials and cooking facilities.

The appeal to RTE shelf-stable meat products lies not only in their convenience, but also in their long shelf life, which is achieved through advanced preservation techniques or combination of different huddles (huddle technology), ensuring the safety and intact sensory qualities without the requirement of refrigeration. As consumer demand for quick and easy meal solutions continue to grow, the market for these products is expanding rapidly. This article explores the different types, processing and preservation methods, critical safety considerations, latest market trends, and limitations of RTE shelf-stable meat products.

2. Types of RTE shelf-stable meat products

A meat product with a water activity (a_w) of less than 0.85 is usually considered shelf stable and would not support the growth of pathogenic microorganisms. Water activities of ≤0.85 and ≤0.70 are critical for controlling the growth of *Staphylococcus aureus* and molds in meat and meat products.

The RTE shelf-stable meat products come in different forms, catering to the requirements of the consumers. Some common types include:

2.1. Canned meats:

Canning is a very old method of preservation involving preservation of meat in hermetically sealed metal cans. Application of high heat under pressure destroy

pathogens and enzymes responsible for spoilage. Canned meats are shelf stable up to 2 years at ambient temperature. E.g. – Canned ham, corned beef, canned chicken etc.

2.2. Dehydrated and dried meats:

The dehydration process removes moisture, reducing the a_w in the meat, which inhibits microbial growth. These products are often seasoned with spice, herbs, and marinades to enhance flavour.

Here are some dried meat products from different countries:

- Biltong: A dried meat product that originated in Southern Africa, biltong is made from meat that is cured, salted, spiced, and air dried. Biltong is often made from beef, but can also be made from game meats like kudu, springbok, wildebeest, and ostrich. Biltong is softer and saltier than jerky, and is made without heat.

- Jerky: A popular snack made from cured meat, usually beef or turkey, that is sliced, marinated, and then roasted or smoked at a low temperature. Jerky is popular around the world, including Europe, where some varieties are seasoned with red pepper and fennel seed.

- Pemmican: A food mix that was traditionally made from dried meat and rendered fat, but modern versions include bison, beef, berries, and other natural ingredients. Pemmican has a long shelf life and can sustain an individual for months.

- Bresaola: An air-dried and salted beef product.
- Carne seca: A Mexican dried beef product.
- Cecina: A salted and dried or cured meat product.
- Charqui: A lean meat dried to prevent spoilage.
- Droëwors: A South African snack food.
- Kilishi: A Hausa dish of spiced dried beef, chicken, mutton or goat meat.
- Mojama: An Andalusian cured tuna delicacy.
- Pastırma: A spiced dried beef product.
- Slinzega: An air-dried meat product from the Italian Alps.

2.3. Intermediate Moisture Meats (IMM):

In general, the intermediate moisture foods (IMFs) having water activities (a_w) between 0.6 - 0.85 and moisture contents of 10–50%. Similarly, the intermediate (IM) meat products are produced by lowering the a_w (0.90-0.60) and moisture contents of 15–45% that inhibits microbial growth while maintaining a desirable texture and flavor. But IMMs are susceptible to yeast and mold growth. Such products are stable at ambient temperature and humidity and are produced by a number of methods:

i) *Partial Drying:* This method involves removing a portion of the water content from the meat through controlled drying processes. The goal is to reduce the water activity to a level that prevents microbial growth while retaining enough moisture to keep the meat palatable.

ii) *Osmotic Drying Using Humectants:* In this process, meat is soaked in a solution containing humectants such as glycerol, salt, or sugar. These substances draw out water from the meat through osmosis, lowering the water activity. Humectants also help retain moisture within the meat, preventing it from becoming too dry.

iii) *Dry Infusion:* This technique involves infusing the meat with dry ingredients that bind water, such as salts and sugars. The dry ingredients are mixed with the meat, which absorbs them, reducing the water activity. This method is often used for products like jerky.

iv) *Formulation:* This method combines various ingredients, including humectants, salts, and preservatives, to create a product with the desired water activity. The formulation is carefully balanced to ensure the meat remains safe and stable without refrigeration.

v) *Hurdle Technology:* "Hurdle" term coined by Leistner and Rodel in 1976 and "hurdle technology" has been derived by Leistner in 1985. This approach uses multiple preservation methods in combination to achieve the desired shelf stability. The use of hurdle technology in the meat industry is a simple concept but usually requires a strategic combination of hurdles, involving water activity (a_w), temperature (low or high), preservatives (i.e., nitrite), acidity (pH), competitive microorganisms (i.e., lactic acid bacteria), and redox potential (Eh). The hurdles are chosen carefully in order to maximize the preserving effect while minimizing the impact on product quality. Usually, this is achieved by combining processes with synergistic effects. For example, a product might undergo partial drying, be treated with humectants, and then packaged in a modified atmosphere to further inhibit microbial growth. MAP can act synergistically with a number of technologies, such as refrigeration, freezing, canning, aseptic processing etc., resulting in a better-quality product with longer shelf life and increased stability.

vi) *High-Pressure Processing (HPP)*: HPP involves subjecting the meat to high pressure, which inactivates pathogens and spoilage organisms. This method can be used in conjunction with other techniques to enhance the safety and shelf life of IMM.

vii) *Edible Coatings and Active Packaging*: Applying edible coatings that contain antimicrobial agents or using active packaging that absorbs moisture can help maintain the quality and safety of IMM. These methods provide an additional barrier against microbial contamination.

2.4. Retort Meats: Retort pouches are flexible, heat-sealed bags made from layers of plastic and metal foil. Retort meat foods are produced by placing pre-cooked meat in a retort pouch or container. This is hermetically sealed and heated under high pressure at around 120°C (250°F), a sterilization process that permits storage at room temperature for about three months to one year without preservatives. Retort pouches or "stand up pouches" are lightweight and easy to transport, making them popular for military rations and outdoor activities.

2.5. Cured and Smoked Meats: Products like salami, pepperoni, and other fermented sausages are made shelf-stable through curing (using salt, nitrates, and nitrites) and smoking. These methods reduce the water activity in the meat and add distinct flavors while also inhibiting microbial growth.

2.6. Freeze-Dried Meats: Freeze-drying involves freezing the meat and then reducing the pressure to allow the frozen water in the meat to sublimate directly from the solid phase to the gas phase. This method preserves the meat's nutritional content and flavor while making it lightweight and easy to rehydrate (even up to 90-95%).

3. Processing and Preservation Methods

The production of RTE shelf-stable meat products involves several processing and preservation methods to ensure safety and quality. Given below are some common methods of production of RTE shelf-stable meat products:

i) **Thermal Processing-**Thermal processing, such as canning and retort pouch processing, is a highly effective method for ensuring the safety and shelf life of meat products. This process involves applying heat to destroy pathogens and spoilage microorganisms. The specific temperature and time required depend on factors such as the type of meat, packaging material, and desired shelf life. For example, low-acid canned meats typically undergo processing at temperatures between 115-121°C to ensure the elimination of Clostridium botulinum spores.

ii) **Dehydration-**Dehydration lowers the water activity (aw) of meat products, which is crucial in preventing microbial growth. Most microorganisms require aw above 0.85 to thrive. By reducing water activity below this threshold, dried meat products like jerky become shelf-stable. Modern dehydration techniques, such as vacuum drying and freeze-drying, help retain the sensory qualities of the meat while ensuring a long shelf life.

iii) **Curing and Smoking-**Curing involves applying salt, nitrites, and sometimes sugar to meat, which draws out moisture and creates an environment that inhibits spoilage organisms. Nitrites also contribute to the characteristic pink color of cured meats and help prevent the growth of Clostridium botulinum. Smoking adds an additional layer of preservation by introducing compounds from wood smoke that have antimicrobial

properties. Together, these processes create shelf-stable products with unique flavors.

iv) **Chemical Preservatives-**Chemical preservatives are commonly used in RTE meat products to prevent microbial growth and oxidative rancidity. Sodium nitrite, sodium erythorbate, and citric acid are examples of preservatives that can extend shelf life by inhibiting spoilage bacteria and delaying rancidity. However, there is a growing consumer demand for clean-label products, leading to increased interest in natural preservatives such as rosemary extract and ascorbic acid.

v) **Packaging Strategies-**Packaging plays a critical role in ensuring the shelf stability of RTE meat products. The choice of packaging materials and technologies is guided by the need to protect the product from environmental factors such as oxygen, light, and moisture.

Barrier Properties-Packaging materials for shelf-stable meat products must provide effective barriers against oxygen and moisture. Oxygen exposure can lead to oxidative rancidity, while moisture can encourage microbial growth. Common packaging materials include multilayer laminates, which combine plastic, aluminum foil, and other materials to create a strong barrier while remaining flexible and lightweight. Vacuum packaging and modified atmosphere packaging (MAP) are also employed to extend shelf life by removing oxygen or replacing it with inert gases like nitrogen or carbon dioxide.

Active Packaging-Active packaging technologies are increasingly being used in RTE meat products to further enhance shelf life and safety. These technologies include oxygen scavengers, antimicrobial films, and moisture absorbers. Oxygen scavengers, placed inside the packaging, absorb residual oxygen, preventing oxidative spoilage. Antimicrobial films are coated with substances that inhibit microbial growth, providing an additional layer of protection.

4. Quality and Safety Considerations

Ensuring the quality and safety of RTE shelf-stable meat products is of utmost importance. Several factors must be considered, including microbial safety, sensory attributes, and nutritional quality.

i) **Microbial Safety-**Microbial safety is the primary concern in producing RTE shelf-stable meat products. The combination of thermal processing, reduced water activity, and chemical preservatives effectively reduces the risk of microbial contamination. However, improper handling during processing or packaging can introduce pathogens such as Listeria monocytogenes or Staphylococcus aureus. Therefore, strict adherence to Good Manufacturing Practices (GMP) and Hazard Analysis Critical Control Points (HACCP) is essential.

ii) **Sensory Quality-**Sensory attributes such as flavor, texture, and color are critical for consumer acceptance. Prolonged storage or exposure to adverse conditions can lead to changes in these attributes. Oxidative rancidity is a common issue in shelf-stable meat products, resulting in off-flavors and a decline in quality. The use of antioxidants, both natural and synthetic, can mitigate this problem. Textural changes, such as hardening or loss of juiciness, can occur due to moisture migration or protein denaturation during storage.

iii) **Nutritional Quality-**The preservation methods used in RTE shelf-stable meat products can impact their nutritional content. For example, thermal processing can lead to the loss of heat-sensitive vitamins like thiamine and vitamin C. However, these losses are generally minimal compared to the benefits of having a shelf-stable product. Advances in processing and packaging technologies aim to minimize nutritional degradation while maximizing shelf life.

5. Emerging Market Trends and Innovations

The market for RTE shelf-stable meat products is evolving, driven by consumer demand for convenience, clean labels, and novel flavors. Some emerging trends and innovations include:

i) **Clean-Label Products**: There is a growing consumer interest in products made with natural ingredients and without artificial preservatives. This has led to the development of natural preservation techniques, such as using plant extracts with antioxidant and antimicrobial properties.

ii) **High-Pressure Processing (HPP)**: HPP is a non-thermal preservation method that uses high pressure to inactivate pathogens and extend shelf life while preserving the sensory and nutritional qualities of the meat. This method is gaining popularity in the production of premium RTE meat products.

iii) **Ethnic and Gourmet Flavors**: Consumers are increasingly seeking variety in their food choices, leading to the introduction of RTE shelf-stable meat products with ethnic and gourmet flavors. These products often incorporate unique spices, herbs, and cooking techniques from various cuisines around the world.

iv) **Sustainability**: Sustainability is becoming a key consideration in the production of RTE meat products. This includes the use of eco-friendly packaging materials, reducing food waste through innovative preservation techniques, and sourcing meat from sustainable and ethical farming practices.

6. Limitations and Challenges

1. *Cost*-One of the major challenges of advanced processing technologies is the high cost of equipment and operation. Techniques such as freeze-drying and HPP require substantial investment, which can be a barrier for small and medium-sized enterprises.
2. *Texture and Flavor Alterations*-Certain processing methods, especially thermal ones, can alter the texture and flavor of meat products. For instance, the high temperatures used in canning can lead to a softer texture and a change in taste, which may not always meet consumer expectations.
3. *Nutritional Loss*-While many processing methods aim to preserve nutritional content, some can lead to nutrient loss. For example, hot air drying can reduce the levels of certain vitamins and minerals, impacting the overall nutritional profile of the meat.
4. *Environmental Impact*-The environmental impact of processing technologies is a growing concern. Energy-intensive methods like freeze-drying and the production of specialized packaging materials for HPP can contribute to a larger carbon footprint. The industry is increasingly focused on finding more sustainable solutions to mitigate these impacts.

7. Conclusion

The ready-to-eat shelf-stable meat products are gaining popularity among the fast-paced modern consumers as they provide convenience, variety, safety, and extended shelf life besides protecting sensory qualities. The success of these products depends up on selecting appropriate preservation techniques, packaging materials, and processing methods to ensure product quality and safety. The ultrasound-assisted thermal technology, if used can significantly reduce the number of food-borne pathogens in ready-to-eat foods. Further, treatment with cold atmospheric plasma (CAP) can inactivate *Listeria* and *Escherichia coli* in ready-to-eat meat products However, challenges such as high costs, potential changes in texture and flavor, and environmental concerns remain. The future of this sector will likely be shaped by ongoing innovations, including the integration of nanotechnology, hybrid processing methods, intelligent packaging concepts, advanced monitoring technologies, and sustainable practices. These advancements will continue to drive the evolution of RTE shelf-stable meat products with improvements and prolongation of shelf life, thereby meeting the needs of modern consumers, while addressing environmental and economic challenges.

****References can be requested from the authors****

Chapter-13

Development of Designer and Functional Meat Products Using Natural Preservatives and Additives

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1. Introduction

The golden proverb "Food is the best medicine" is now receiving renewed interest because of increasing incidence of life style diseases. Today the leading causes of death in the world are cardiovascular disease, diabetes and cancer (Wolfe *et al*., 2003; Kaul, 2012). It has been estimated that around 32% deaths due to these diseases could be avoided by dietary manipulations (Wolfe *et al*., 2003). India leads the world with diabetic patients, and the prevalence is more in younger generation because of drastic change in life style (Kaveeshwar and Cornwall, 2014). The International Diabetic Federation (IDF) has estimated that the total number of diabetic subjects was 50 million in India in the year 2010 and this is further set to rise to 87 million by the year 2030 (Unwin *et al*., 2009). World Health Organisation (WHO) projects that diabetes will be the 7th leading cause of death in 2030.

There is increased awareness among consumers about the fact that foods are associated directly to their health. Therefore, awareness about functional foods is increasing day by day. At the same time preference for delicious, tasty, ready-to-eat (RTE) food products is also increasing because of changing life styles and the busy schedules of working people, high mobility groups, change in eating habits of children and its convenience and easy acceptability. So, there is need for development of ready-to-eat functional meat products. Hence, nowadays there is lot of research on developing functional meat products using plant products as natural preservative or additive which are also expected to enrich their functional value. This paper briefly discuss about the development designer and functional meat products, using natural preservatives and a few natural additives to increase the functional quality of meat products mostly based on our own works.

2. Functional Food

Functional foods are those foods having some special components in them, besides basic nutrients, which perform some special physical, chemical, biological and health promoting functions (Gibson and Williams, 2000). They are also called as diet foods, health promoting foods, nutraceutical foods or designer foods. They may also

have higher levels of certain nutrient already present in the basic foods or may have lower levels of few unwanted substances in them. The functional foods may have general or specific health benefits like cardiac, gut, renal, anti-carcinogenic, vision and health promoting properties. However, these functional foods are not for therapeutic purpose, but for prevention only (Gibson and Williams, 2000).

Excessive amounts of omega-6 PUFA and a very high omega-6/omega-3 ratio, promote the pathogenesis of many diseases including cardiovascular disease, cancer, inflammatory and autoimmune diseases, whereas, increased levels of omega-3 PUFA (a low omega-6/omega-3 ratio) exert suppressive effects (Simopoulos, 2002). The increase intake of dietary fibre is associated with reductions in plasma LDL cholesterol, reduced risk of major dietary problems such as obesity, diabetes, cardiovascular and gastrointestinal disorders including constipation, inflammatory bowel diseases etc (Biswas *et al*., 2011). Development of omega-3 and fibre enriched functional food could be a potential solution for preventing such diseases. The strategies for preparing functional meat products involve modification at meat product processing level. The functional meat products can be produced by the addition of selective ingredients which have some special health promoting properties like flaxseed for enriching omega 3 fatty acids and oats for enriching fibre content.

3. Meat and Meat Products

Meat and meat products are generally recognized as good sources of high biological value proteins, essential fatty acids, fat-soluble vitamins, minerals, trace elements and bioactive compounds. Chicken meat is very popular in India because of its taste, health benefits and nutritional value followed by freedom from religious taboos, affordable price and easy availability. Poultry meat has a relatively high concentration of polyunsaturated fatty acids (PUFA) (Bourre, 2005). Increased content of unsaturated fatty acids causes lipid oxidation which creates a risk to human health because of the possibility of atherogenic, mutagenic and cytotoxic compounds formation (Fernandez *et al*., 2005). Long term storage leads to deterioration in its nutritional quality by development of rancid flavour, colour fading and affecting its essential sensory traits (Estevez *et al*., 2005). The most common strategies for preventing lipid oxidation are by the use of antioxidants (Tang *et al*., 2001).

3.1. Restructured meat products

In its broadest sense, any meat products that are partially or completely disassembled and then reformed into the same or different forms are called restructured products. Lipid oxidation is one of the major problems in the development of new convenient meat products (Gray and Pearson, 1987). Oxidation and colour fading are two major problems in retail acceptance of the restructured meat (Pearson and Dutson, 1987). A highly acceptable restructured chicken slice without addition of extra fat has been developed as a novel meat product (Mandal *et al*., 2002). But increase in TBA and

tyrosine values of this product were observed under refrigerated storage. The product was found to be acceptable only up to 10th day of storage under refrigeration. On 15th day, product had pale appearance and unpleasant odour, due to oxidation. Gizzard was successfully added in the same restructured chicken block up to 50% without any adverse effect (Mandal *et al*., 2011). The gizzard added product was also prone to oxidation both under refrigerated and frozen storage (Sudheer *et al*., 2011a). Sensory scores of the restructured chicken block decreased significantly on the 10th day of storage (Sudheer *et al*., 2011b). The gizzard added product also had a storage life only up to 10th day under refrigerater. Use of natural antioxidants has been found to have an ameliorating effect on these undesirable changes produced via oxidation during storage.

4. Natural Preservatives

Synthetic antioxidant like butylated hydroxy anisole (BHA) and butylated hydroxy toluene (BHT) have toxic potential and carcinogenic effect (Jayaprakasha *et al*., 2003). Growing awareness among consumers towards the health aspect has increased the interest on natural antioxidants. Use of natural antioxidant can replace the toxic effect of chemical preservatives and contributes health promoting effect and thereby makes the food functional. Natural antioxidants found in the plants and fruits have gained a considerable momentum for their role in preventing the auto-oxidation in fat rich foods (Reddy *et al*., 2005). Mature drumstick leaves (*Moringa oleiofera*) are the potent source of phenolics and have immense neutraceutical value for the development of functional meat products of commercial importance (Das *et al*., 2012). Drumstick leaf powder is already proven as natural antioxidant in meat product in our Lab (Najeeb *et al*., 2014, 2015).

To extend the storage stability of meat and products various additives with antioxidant and antibacterial properties have been tried with varying degrees of success. Natural antioxidants are known to protect cells from damage induced by oxidative stress due to the production of free radicals, which are generally considered to be the cause of aging, degenerative diseases and cancer. Based on growing interest in free radical biology and the lack of effective therapies for most chronic diseases, the usefulness of antioxidants in protection against these diseases is warranted. Putting emphasis on these facts, researches on natural antioxidants are the current trends in meat and allied industry.

5. Functional Meat Products with Natural Preservatives

The use of natural preservatives to increase the shelf-life of meat products is a promising technology since many herbs, plants, fruits, and vegetable extracts or powders have antioxidant and antimicrobial properties (Biswas *et al*., 2012). Presently, the use of natural antioxidants in meat systems is limited. In traditional Indian preparations, leaves and fruits are added to meat as flavour enhancers either in raw

chopped form or as ground paste with other spices. The total phenolics and free radical scavenging activity of these ingredients were retained even after heating indicated that the active constituents were resistant to thermal effect, hence, could be used as natural preservatives in meat products processing and also increase the functional quality (Kannat *et al*., 2005).

5.1. Use of Leaves as Natural Preservatives and Functional additive

5.1.1. *Drumstick* leaves (*Moringa oleifera. L*)

The leaves are rich in proteins, essential amino acids such as methionine, cystine, tryptophan and lysine, vitamin C, beta-carotene, riboflavin, nicotinic acid, pyridoxine, potassium, copper, calcium, iron and phosphorus. It is reported to be a potent source of natural antioxidants like ascorbic acid, alpha tocopherol and other flavonoids and carotenoids, and thus enhancing the shelf life of fat containing foods (Gupta *et al*., 1989; Dillard and German, 2000). Polyphenolic compounds act as chain-breaking peroxyl radical scavengers which lead to the inhibition of lipid peroxidation and also prevent low density lipoprotein oxidation (O'Byme *et al*., 2002).

Caceres *et al.* (1991) reported that *drumstick* leaf juice have antimicrobial properties. The *drumstick* leaf juice, powder and water extract displayed a potential antibacterial activity against both gram negative and gram positive bacteria (Rahman *et al.,* 2009). The sensory quality of the restructured chicken slices containing drumstick leaf powders were not affected even up to 20 days of storage under refrigeration (Najeeb *et al*., 2014).

5.1.2. *Mint leaves* (*Mentha spicata. L)*

Mint leaves have potent antioxidant properties due to the presence of eugenol, caffeic acid, rosmarinic acid and α-tocopherol (Zheng and Wang, 2001; Dorman *et al*., 2003). Marinova and Yanishlieva (1997) reported that *Mentha spicata L*. was able to retard the autooxidation of sunflower oil at 100^0C. Decrease in enzymatic lipid peroxidation has also been reported by aqueous and alcoholic extracts of mint (Shobana and Naidu, 2000). Crude extract of *Mentha spicata* was found to have better antibacterial activity against *Escherchia coli, Bacillus subtilis, Shigella flexeneri, Staphylococcus aureus, Pseudomonas aeruginosa* and *Salmonella typhi.* Among them, *E. coli* and *Pseudomonas* were shown to be the most sensitive (Naseem *et al*., 2011). It was observed that the essential oil from *M. spicata* has a dose dependent activity against bacteria among which gram positive organisms were more sensitive than gram negative.

Application of antioxidant activity of mint leaf has been reported in meat and meat products. After four weeks of chilled storage, TBARS in irradiated meat containing mint leaf extract (0.1%) was half of that in untreated meat and it was comparable to that of BHT treated products (Kannat *et al*., 2005). No significant differences were observed among the TBA values of restructured chicken slices added with BHT (200ppm) and mint leaf powder (1%) during 20 days of storage under

refrigerator (Najeeb *et al*., 2014). Restructured chicken slices prepared with mint leaf powders showed significantly lower microbial counts compared to control (Najeeb *et a*l., 2015).

5.1.3. *Curry* leaves (*Murraya koenigii. L*)

Phytochemical studies on leaves, stem, bark and root of this plant revealed that the presence of carbazole alkaloids such as murrayanine, girinimbine, mahanimbine, murrayafoline-A and triterpene had vasorelaxing, anticarcinogenic and antiplatelet activity in addition to antioxidant and antimicrobial properties (Ningappa *et al*., 2008). Mahanine is reported to have high antioxidant activity compared to BHA and alpha tocopherol (Gupta *et al.,* 2011). The protein designated as APC (antioxidant protein from *curry* leaves) isolated from *curry* leaves showed highly significant broad spectrum antibacterial activity against *E. coli* and *Staphylococcus aureus, Vibrio cholerae, Klebsiella pneumoniae, Salmonella typhi and Bacillus subtilis* (Ningappa *et al.,* 2008). It was also found that methanolic extract of *curry* leaves had potent antibacterial activity (Gupta *et al.,* 2011).

Curry leaf powder at a concentration as low as 0.2% is found to be a very effective inhibitor of primary and secondary oxidation products in raw ground and cooked goat meat patties stored under refrigeration (4±1^{o}C). Reduction in TBARS values were observed in chicken patties treated with *curry* leaf extract (2%) compared to control during eight days of storage under refrigeration. Interestingly, it was reported that chicken patties treated with BHT had a higher TBARS values than curry leaves extract treated samples (Devatkal *et al*., 2011). No significant differences were observed on the tyrosine values of restructured chicken slices added with *curry* leaf powders (1%) throughout the storage of 20 days at refrigerator (Najeeb *et al*., 2014). Raw goat meat with *curry* leaf powder (0.2%) had significantly lowered free fatty acid content than control during nine days of refrigerated storage (Das *et al*., 2011). Restructured chicken slices prepared with *curry* leaf powders (1%) did not show any significant differences in the FFA values during the entire storage period.

5.2. Use of Fruits as Natural Preservatives and Functional Additives

5.2.1. *Red grapes* (*Vitis vinifera*)

Grapes are rich source of polyphenolic compounds. It mainly includes anthocyanins, flavonols, stilbenes and phenolic acids. Flavonoids and other plant phenolics have been reported to have antioxidant activity (Frankel *et al.,* 1995) and antimicrobial activity (Renaud and Longeril, 1992). The most notable bioactivity of phenolic compounds from grapes is the antioxidant activity by free radicals scavenging, inhibition of lipid oxidation, reduction of hydroperoxide formation has been widely studied (Meyer *et al.,* 1997). All parts of grapes are having potent antimicrobial activity. The ascending order of the antimicrobial activity was in flesh, whole fruit grape extracts, fermented pomace, skin, leaf and seed (Xie *et al*., 2010).

Addition of grape extract (60 mg total phenolic compounds / kg of meat) provided greater stability to the chicken meat balls with regard to red discolouration (Selani *et al.,* 2010). It was found that addition of grape seed extract did not affect the initial changes in flavor scores in both irradiated and non-irradiated whole chicken breasts (Rababah *et al.,* 2005). No significant differences were observed on the SPC and TBA values of restructured chicken slices added with red grapes powders (1%) throughout the storage period (Najeeb, 2015).

5.2.2. *Gooseberry* (*Emblica officinalis*)

Gooseberry is the richest source of antioxidants like vitamin C, emblicanin A and B, punigluconin, pedunculagin, superoxide dismutase, catalase, gluthathione peroxidase, tannin, trigalloyl, polyphenol, flavonoids, ellagic acid and phyllembic acid (Anilakumar *et al.,* 2004). Gooseberry has also been reported to possess antifungal, antibacterial and antiviral activities (Rani and Khullar, 2004). Gooseberry is reported to possess high antibacterial activity against *E. coli, Klebsiella pneumoniae, Pseudomonas aerugenosa and Salmonella paratyphi* (Saeed *et al.,* 2007). Antimicrobial activity of aqueous and methanolic extract of gooseberry was tested against different microorganisms by Vimela *et al.* (2009). Restructured chicken slices added with gooseberry powder (1%) showed significantly lower SPC and TBA values compared to control throughout twenty days of storage (Najeeb *et al*., 2015).

5.2.3. *Tomato* (*Solanum lycopersicum*)

Tomato contains phytochemicals such as lycopene, folate, vitamin C, phenolics and flavonoids which are having beneficial health effects (Agarwal and Rao, 2000). Lycopene is the major carotenoid present in tomato and a highly potent antioxidant that provides protection against cellular damage caused by reactive oxygen species and it is also reported as a potent cancer therapy agent (Rao and Agarwal, 1999).

Addition of tomato powder at 2% level in frankfurters decreased the oxidation during 60 days of refrigerated storage (Eyiler and Oztan, 2010). Restructured chicken slices added with tomato powders at 1% had significantly lower TBA and FFA values than control products throughout the storage period of 20 days (Najeeb *et al*., 2014). The sensory scores of restructured chicken slices added with tomato powders (1%) were not affected even up to 20 days of storage under refrigeration (Najeeb *et al*., 2015).

6. Functional Chicken Chips using Natural Additives

Nowadays preference for any kind of chips as snacks is high among the consumers. Chicken chips incorporated with natural additives are expected to increase the functional value and thus make it acceptable product with added health benefits. Hence, a study (Kasthuri, 2015) was conducted for the development of functional chicken chips using natural additives viz. flaxseed (FSP), oats (OP), drumstick leaf and

Jamun seed powder and its storage stability at room temperature. Standardization of recipe and procedure for the preparation of functional chicken chips was done using flaxseed and oats powder by replacing meat. Drumstick leaf (DLP) and Jamun seed powder (JSP) as natural antioxidant and functional additive in chicken chips at room temperature storage was evaluated. Chicken chips prepared by microwave cooking method showed significantly higher sensory scores compared to deep fat frying and hot air oven cooking. Then, 4% FSP and 6% OP were selected through separate experiment for incorporation into chicken chips recipe for the preparation of functional chicken chips (FCC) by replacing meat.

FCC containing 1, 2, 3% DLP and JSP revealed that products with 1% DLP or JSP were highly acceptable and hence, selected for storage study. Three separate FCCs incorporated with 1% DLP, 1% JSP and 0.5% DLP+0.5% JSP separately were selected for storage studies under room temperature. No significant difference in TBA value between the products throughout the storage study up to 60 days was observed. However, the values were far below the threshold value for spoilage due to oxidation. No significant difference in tyrosine value was found between the products. FCC with 1% DLP, 1% JSP, 0.5% DLP+0.5% JSP revealed no significant difference in sensory scores on all the days of storage. All the products had very good sensory score (above 7 in 8 point hedonic scale) throughout the storage. The standard plate count and Yeast and mould count were much below the permissible limit for all the products.

7. Health Benefits of Natural Preservatives

Natural antimicrobials though primarily used for killing or inhibiting bacteria, have several beneficial effects. LAB in fermented foods in addition to their antimicrobial activity produces probiotic health benefits. Curry leaves commonly used as flavouring agent in many traditional dishes are gaining attention because of its medicinal values such as anticarcinogenic (Chevallier, 1996), antiplatelets and vasorelaxing effects (Wu *et al.*, 1998). Plant phenols act as antioxidant in food system has potent antioxidant and other health benefits. Similarly hypertensive effects of oleuropein in olive leaves and fruits were also reported. Moreover, nisin, pediocin and lactococcin are given GRAS status and are naturally present in many food products. Lycopene helps in the prevention of cardiovascular disease and cancers of the prostate or gastrointestinal tract (Clinton, 1998). Ginger is anti-inflammatory and prevents against ovarian and colorectal cancer. Garlic reduces the risk of cancer, stroke and aging. Carnosine, vitamin E, ascorbic acid are potent antioxidants. Chitosan acts as a fat binder and thereby helps to lose body weight. It is also shown to have beneficial effect on cholesterol, ulcers, osteoporosis and blood pressure.

8. Future Research Need

The recent consumer interest in the therapeutic properties of herbs has led to an increase in research for herbal based food products. Antioxidant and antimicrobial

properties of essential oils and other components of herbs and spices are widely used as food bio-preservatives to extend the shelf life of meat foods. Further research should investigate the effect of natural preservatives as functional additive. Also, various plants, herbs present in nature with potential preservative actions in food systems are yet to be discovered. The dearth of systematic research and availability of relevant toxicology data is one of the limiting factors in their utilization. Future studies may be focused on the applicability of such systems to meat and meat products to replace chemical preservatives with natural preservatives, also as functional additive.

****References can be requested from the authors****

Chapter-14

Converting low value meat into reformulated/restructured meat products for higher profitability

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1. Introduction

The meat industry encompasses a wide variety of animals, including cattle, buffalo, goats, sheep, and poultry. The slaughtering process generates a range of meat cuts, which are categorized based on their market value, tenderness, and consumer demand. Low-value cuts typically include parts of the animal that are tougher, contain more connective tissue, or are less desirable for direct sale as fresh meat. These cuts are often utilized in processed meat products, traditional dishes, or exported for specific markets. The meat industry faces a constant challenge of adding value to underutilized and low-value meat cuts. Low-value meat cuts refer to parts of an animal that are typically less desirable due to their toughness, high connective tissue content, or less favorable location on the carcass. These cuts generally require more cooking time or specific preparation methods to become tender and flavorful, and as a result, they are often sold at lower prices compared to premium cuts like steaks or tenderloins. Despite being less popular, these cuts are nutritionally similar to higher-value cuts and can be transformed into delicious and valuable products with the right processing techniques. Traditionally, these cuts are often sold at lower prices or used in less profitable ways, such as in ground meat or animal feed. However, with advancements in food processing technology, these low-value cuts can now be transformed into restructured meat products, which can be marketed as premium items. Restructured meat products are those that have been altered in shape, texture, and sometimes flavor, to resemble higher-quality cuts of meat. This process not only enhances the economic value of the meat but also contributes to reducing food waste.

2. Common low-value meat cuts

i) **Chuck:**
   - Location: The shoulder area
   - Characteristics: Chuck cuts are tough and contain a lot of connective tissue and fat. They are often used in ground beef or slow-cooked dishes like stews and pot roasts.
   - Example Cuts: Chuck roast, shoulder steak, chuck-eye steak.

ii) **Brisket:**
   - Location: The lower chest or breast of the cow.

- Characteristics: Brisket is a tough, fatty cut that benefits from long, slow cooking methods like braising or smoking. It's commonly used in barbecue and corned beef.
- Example Cuts: Whole brisket, flat cut, point cut.

iii) **Shank:**

- Location: The leg portion of the animal.
- Characteristics: The shank is a very tough and sinewy cut due to its high collagen content, making it ideal for slow cooking methods like braising, which break down the collagen into gelatin.

iv) Example Cuts: Beef shank, lamb shank, veal shank.

v) **Flank:**

- Location: The abdominal muscles or lower chest of the animals
- Characteristics: Flank steak is lean with a distinct grain, making it tougher than more marbled cuts. It is often marinated and cooked quickly at high heat, then sliced thinly against the grain to maximize tenderness.
- Example Cuts: Flank steak, London broil.

vi) **Round:**

- Location: The rear leg of the cow.
- Characteristics: Round cuts are lean and tough due to the muscles' constant use. They are often used for roast beef, ground beef, or in slow-cooked dishes.
- Example Cuts: Top round, bottom round, eye of round, rump roast.

vii)**Plate:**

- Location: The lower front ribcage area of the cow.
- Characteristics: This area includes tougher, fattier cuts that are often used for short ribs or in ground beef. It is also the source of skirt steak.
- Example Cuts: Short ribs, skirt steak, and hanger steak.

viii) **Neck and Shoulder (for lamb, pork, and poultry):**

- Location: The neck and shoulder area.
- Characteristics: These cuts are generally tough and have a lot of connective tissue. They are typically used in stews, ground meat, or slow-cooked dishes.
- Example Cuts: Neck chops (lamb), shoulder roast (pork), and neck (chicken).

3. Characteristics of low-value cuts

Low-value cuts are typically tough, have high connective tissue content, and may include off-cuts, such as shank, brisket, and flank. These cuts are less tender due to the higher amount of collagen, which requires more intensive processing to convert into a palatable product. The fat content in these cuts can also vary, which affects the texture and flavor of the final product.

4. Utilization of low-value meat cuts in India

Traditional culinary use

In India, low-value cuts are often utilized in traditional cooking methods, which are well-suited to tenderizing tougher meats. These methods include:

- *Slow-Cooking*: Used extensively in Indian cuisine, where tough cuts are cooked slowly in curries or stews to break down connective tissues.
- *Minced Meat (Kheema)*: Low-value cuts are frequently ground into mince and used in various dishes, such as kebabs, koftas, and fillings for samosas.
- *Bone broths and stocks*: Bony parts like the neck, back, and shank are used to prepare rich broths and soups, which are a staple in many Indian households.

Processed meat products

In the industrial meat processing sector, low-value cuts are often transformed into processed meat products, including:

- *Sausages and patties*: Ground meat from low-value cuts is commonly used in making sausages, patties, and other processed meat products.
- *Restructured meat products*: These products involve binding smaller pieces of meat into a cohesive product, which can be marketed as higher-value cuts.
- *Canned and ready-to-eat meals*: Low-value cuts are also used in canned meat products and ready-to-eat meals, which are gaining popularity in urban areas.

Export market

India exports a significant amount of buffalo meat, including low-value cuts, to countries where these cuts are more appreciated or where cost-sensitive markets exist. These exports are often in the form of frozen or processed meat products.

5. Raw material selection and preparation of restructured meat products

The first step in the production of restructured meat products is the selection and preparation of raw materials. Low-value cuts, such as trimmings, tendons, and other by-products, are often used. These cuts are rich in connective tissue and fat, which can be challenging to process but are essential for creating a product with desirable texture and flavor.

6. Preparation techniques of restructured meat product

Before restructuring, these cuts must be properly prepared, which may involve trimming, grinding, or chopping the meat into smaller pieces. The meat may also undergo mechanical tenderization to break down the connective tissues, making it easier to bind and form into a new shape. Marination or the addition of tenderizing agents like enzymes can also be employed to improve the texture.

Restructuring meat involves binding smaller pieces of meat into a cohesive, uniform product that mimics higher-quality cuts. Several methods can be used to

achieve this, including the use of binding agents, mechanical restructuring, and thermal processing.

Binding Agents

Binding agents are critical in restructured meat products as they help hold the meat particles together. Commonly used binding agents include salt, phosphates, transglutaminase (often referred to as "meat glue"), and non-meat proteins like soy or milk proteins. Salt and phosphates improve water retention and protein extraction, which enhances the binding of meat pieces. Transglutaminase acts as a catalyst for cross-linking proteins, providing a strong bond between meat particles.

Mechanical Restructuring

Mechanical processes such as tumbling, massaging, and forming are used to ensure the even distribution of binding agents and to promote the formation of a cohesive structure. Tumbling involves rotating the meat in a drum, which facilitates the extraction of muscle proteins that help bind the meat pieces. Massaging serves a similar purpose but with gentler action. After sufficient binding, the meat is formed into the desired shape using molds or casings.

Thermal Processing

Thermal processing, such as cooking or freezing, is often the final step in restructuring. Cooking helps set the structure of the meat, making it firm and sliceable. Freezing, on the other hand, can be used to stabilize the product for further processing or storage.

7. Formulation and flavoring of restructured meat product

The formulation of restructured meat products involves balancing the right amount of meat, fat, binding agents, and other ingredients to achieve a product with desirable texture, flavor, and appearance. Spices, flavor enhancers, and smoke flavors may be added to replicate the taste of traditional meat cuts. Fat content is carefully controlled to ensure a juicy product without excessive greasiness. In some cases, fillers such as breadcrumbs or starch may be added to improve texture and reduce cost.

8. Benefits of restructured meat products

The conversion of low-value meat cuts into restructured meat products offers several benefits:

Higher economic value

By converting lower-cost cuts into higher-value products, meat processors can significantly increase their profit margins. Restructured products can be sold at prices comparable to premium cuts, providing a better return on investment.

Resource utilization

Restructured meat products contribute to more efficient use of the entire animal, reducing waste and improving the sustainability of meat production. This

approach aligns with the growing consumer demand for sustainable and ethical food products.

Consumer acceptance

Modern restructuring techniques have advanced to the point where restructured meat products can closely mimic the appearance, texture, and flavor of whole-muscle cuts. This has led to increased consumer acceptance and demand for these products.

9. Challenges and considerations

Despite the benefits, there are challenges associated with producing restructured meat products:

Quality consistency

Maintaining consistent quality in restructured meat products can be challenging due to the variability in the raw materials. Differences in fat content, connective tissue, and moisture levels can affect the final product's texture and flavor.

Consumer perception

Some consumers may be skeptical of restructured meat products, viewing them as inferior or overly processed. Transparency in labeling and marketing, along with education on the benefits and safety of these products, is essential to gaining consumer trust.

Regulatory and safety concerns

Regulatory agencies closely monitor the use of additives and processing methods in restructured meat products to ensure they are safe for consumption. Meat processors must adhere to strict guidelines to avoid potential health risks associated with improperly processed or stored products.

10. Technological advancements in the field

The field of meat restructuring has seen significant technological advancements, particularly in the use of enzymatic binders and novel processing techniques. Innovations in 3D printing and plant-based binding agents are also emerging, offering new possibilities for creating meat analogs and enhancing the functionality of restructured products.

3D Printing

3D printing technology has the potential to revolutionize meat restructuring by allowing precise control over the texture, shape, and composition of the product. This technology could enable the creation of customized meat products that meet specific dietary or sensory preferences.

Plant-based binding agents

The development of plant-based binding agents is gaining traction as a way to produce restructured meat products that cater to the growing demand for plant-based and flexitarian diets. These agents can provide similar binding properties as

traditional animal-based proteins, with the added benefit of being allergen-free and suitable for vegetarian or vegan products.

11. Conclusion

Restructured meat products offer a valuable solution for the meat industry to make better use of low-value cuts, turning them into profitable and high-quality products. While there are challenges, the benefits in terms of economic value, resource utilization, and consumer acceptance are significant. As technology continues to evolve, the possibilities for innovation in this area are vast, promising a future where restructured meat products play a central role in a more sustainable and efficient meat industry.

****References can be requested from the authors****

Chapter-15

Interventions for Utilization of Animal Byproducts for Health and Wealth

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1. Introduction

Things obtained by the slaughter of food animals which is not part of the main animal carcase is termed as animal byproducts. Various animal byproducts such as viscera, meat, fat or lard, skin, feet, abdominal and intestinal contents, bone, feather and blood are obtained from slaughterhouses. These byproducts may make up from around 33% to around 43% (w/w) of the live weight. The byproducts derived from slaughter and processing of cattle, pigs and broilers may represent about 49, 44 and 37% of the total live weight, respectively. In the specific case of chickens, blood represents about 2–6% of the total bird weight, and feathers could be up to 10%. There is a growing sense that most of times these byproducts are under-utilized and can be transformed into valuable resources if treated in the correct manner. Some valuable raw materials have a strong economic potential like the production of new products and functional ingredients with a significant added-value. It is desirable to process all byproducts into valuable products, for human foods, pet foods, animal feeds, pharmaceuticals, or fertilizer and lately for biodiesel generation.

Adding value to slaughterhouse byproducts implies a degree of innovation that makes a byproduct that could be considered as waste, to be used as raw material subjected to further processing into edible food items desirable to consumers or inedible products with economic profitability (e.g. plastics, pharmaceuticals, energy). In the case of edible items, meat byproducts constitute an excellent source of nutrients like essential amino acids, minerals and vitamins. Another alternative is to produce functional ingredients like bioactive peptides and antioxidants. A good example is blood that has several technological functions such as the increase in protein levels, and the enhancement of the water binding and emulsification capacity. The processing of byproducts can convert a product of low value, or even having relevant disposal costs, into a product capable of covering all the processing and disposal costs, and reducing the environmental damage.

Byproducts such as blood, liver, lung, heart, kidney, brains, spleen and tripe have good nutritive value. For instance, liver is very rich in vitamins while liver and kidney contain a wide variety of minerals and trace elements even though cholesterol content

is quite high. Other products rich in fat tissue like lard or tallow contribute mostly to energy intake. Protein from feathers, bristles, horns, beaks or wool can be only enzymatically hydrolysed after destruction of the keratin structure, either by acid or base treatment, by the use of specific microorganisms or enzymes, by thermochemical pre-treatment, or else by steam flash explosion.

Table 1: Approximate yield of slaughterhouse byproducts from small animals (Sheep and Goat).

S. No	Meat/ Byproduct	Percent yield
1.	Dressed weight	40.00
2.	Paunch contents	22.00
3.	Skin	9.20
4.	Gut and tripe	8.00
5.	Head	5.60
6.	Blood	3.00
7.	Fatty tissue	2.00
8.	Lungs and oesophagous	1.00
9.	Liver	1.20
10.	Hoofs	0.80
11.	Heart	0.40
12.	Kidney	0.40
13.	Spleen	0.20
14.	Pancreas	0.16

(Source: Irshad, A., & Sharma, B. D., 2015)

2. Classification of slaughterhouse byproducts

Animal byproducts fall into two categories *i.e.* "edible" and "inedible." "Edible" byproducts are those byproducts that can be consumed as a food by human beings generally include liver, kidney, heart, brain, intestine, tongue, spleen etc. They are also called as variety meats. On the other hand, those byproducts which cannot be consumed as food by human beings are called "Inedible" byproducts e.g. hides, skins, ear, snout, gallbladder, foetus, hoofs, horns, hair, bristles etc. The basic criterion of division between edible and inedible byproducts depends upon the purchasing power, custom, tradition, food habits, religious outlook etc.

"Offal" refers to meat slaughter byproducts and includes the entire animal that is not a part of the carcass. "Variety meats" include liver, heart, tongue, oxtail, kidney, brain, sweetbreads (thymus and/or pancreas gland depending on the animal's age), tripe (stomach), chitlings and natural casings (intestines), and fries (lamb or calf testicles). In some areas of the world and to different degrees, blood is also utilized as

an edible product for humans. In some countries, meat trimmings from the head are described as "edible offal" or "edible byproduct items," and "edible fats" are fats obtained during slaughter, such as "caul fat" surrounding the rumen and/or stomach, and "cutting fat," which is "back fat" or pork "leaf fat" (kidney fat) or "rumen fat."

The offal is divided into red [head, heart, liver, lungs, melt (spleen), sweetbreads, tail, thick skirt (diaphragm), and tongue] and white [fats, many plies (third stomach), set of guts and bladder, set of tripe (weasand, first, second, and fourth stomach), and rectum] and four feet and trimmings. Blood, hides, and pharmaceuticals are usually considered as a separate category.

2.1. **Edible meat by-products**

Biologically, most noncarcass material is edible, with appropriate cleaning, handling, or processing. Red viscera (the most frequently used edible byproducts) is a term that is often applied to liver, heart, kidney, tongue, and neck sweetbread (thymus), and these products are also marked as "fancy meat."

This noncarcass material is usually separated into categories such as main ingredient (e.g., "fancy meat"), sausage material (e.g., cheeks, head trimmings, pork rinds), pet food, animal feed (often used in this category are blood, lungs, spinal cord, breast fat, bones, and several of the stomachs), and fertilizer.

Various byproducts such as intestines, skin, stomach, bile which can be used for more valuable processed products such as catguts, collagen sheets, sportguts, leather etc., are being used for edible purposes.

2.2. Inedible slaughterhouse byproducts (IESBPs)

Inedible slaughterhouse byproducts represent discards that are unsuitable for human consumption and rejected as wastes (blood and stomach contents) or reprocessed into secondary products (gelatine and keratin extraction, belts, footwear, and pharmaceuticals) as shown in Figure 1. The major inedible byproducts include wool, hair, fiber, skin, bones, horns, bristles, hooves, manure, litter, snout, teeth, trimmings, ligaments and cartilage, feet, manure, rumen contents and glands etc. detail of edible and inedible byproducts are given in table 1.

3. Value added products from slaughterhouse byproducts

3.1. Blood and blood products

Blood proteins, especially plasma component, have relevant functional properties like gelation, foaming agents and emulsification that prompted the use of blood-derived products as value-added ingredients in the food industry and as dietary supplements. For example, fractionated plasma proteins like immunoglobulins, fibrinogen and serum albumin, may be added to food and feed ingredients due to their good gelation and emulsification properties. Some of the plasma proteins have

shown good cross-linking ability of major proteins and protease inhibitory activity or used to enrich in protein products like pasta. Other precipitated blood plasma compounds like fibrinogen and the enzyme thrombin are used under the trade mark fibrimex® (Harimex, The Netherlands) as a binder for meat processing to manufacture restructured meat products. When both thrombin and fibrinogen are mixed and applied to the surfaces of meat pieces, the thrombin enzyme converts soluble fibrinogen into insoluble fibrin polymer giving rise to a half-staggered structure called the protofibril that finally aggregates to form fibers and yielding a three-dimensional network fibrin clot. The resulting gel network gives meat emulsions with modified physicochemical and textural characteristics, increasing the hardness and springiness.

Table 2: The potential uses and preparation of sheep and goat edible byproducts

S. No.	Kind	Storage and preparation	Methods of usage
1.	Liver	Frozen, fresh, or refrigerate Whole, sliced, or grind	Braised, broiled, fry, loaf, patty, and sausage
2.	Kidney	Fresh or refrigerate Whole or sliced	Broiled, cooked in liquid, braised, fried, stew, and soup
3.	Heart	Frozen, fresh, or refrigerate	Whole or sliced Braised, cooked in liquid, roasted, stuff, luncheon meat, patty, loaf, and sausage ingredient
4.	Brains	Frozen, fresh, or refrigerate	Whole Broiled, braised and cooked in liquid, poach, and fried
5.	Tongue	Fresh or refrigerate	Boiled, stew, jelly, grilled, and cooked in liquid
6.	Stomach	Fresh or refrigerate	Honeycomb tripe and container for haggis
7.	Sweetbread	Frozen, fresh, or refrigerate	Whole Fry, broiled, braised, poach with sauce, cream and cooked in liquid
8.	Spleen	Frozen, fresh, or refrigerate	Pie, melt, blood sausage ingredient, and variety meat
9.	Intestine (small and large)	Fresh or refrigerate	Remove manure, soaking, washing, and salting before use Sausage casing
10.	Cheek and head trimmings	Frozen, fresh, or refrigerate	Cooked sausage, stew, and soup
11.	Testicles	Frozen, fresh, or refrigerate	Fried
12.	Lungs	Fresh or refrigerate Haggis	Pet food
13.	Feet	Frozen, fresh, or refrigerate	Jelly

14.	Fat	Frozen, fresh, or refrigerate	Shortening, drippings, sweets, oleomargarine, and chewing gum
15.	Blood	Frozen or refrigerate	Black pudding, sausage, blood and barley loaf
16.	Bone	Frozen, fresh, or refrigerate	Gelatin, soup, jelly, and mechanically deboned tissue

(Source: Irshad, A., & Sharma, B. D., 2015)

The binding strength depends on several factors like the pH and temperature of the meat, the moisture and in the case of restructured meat also the size of meat cuts (binding is stronger for larger particle size) and the direction of meat fibers. The hydrolysis of defibrinated bovine plasma with either commercial enzymes like alcalase or flavorzyme resulted in a mixture of peptides with molecular masses less than 6.50 kDa. The knowledge of the molecular weight distribution is relevant in trying to predict the potential allergenicity, biological activity, taste of the hydrolysate and the types of volatile compounds generated during Maillard reaction.

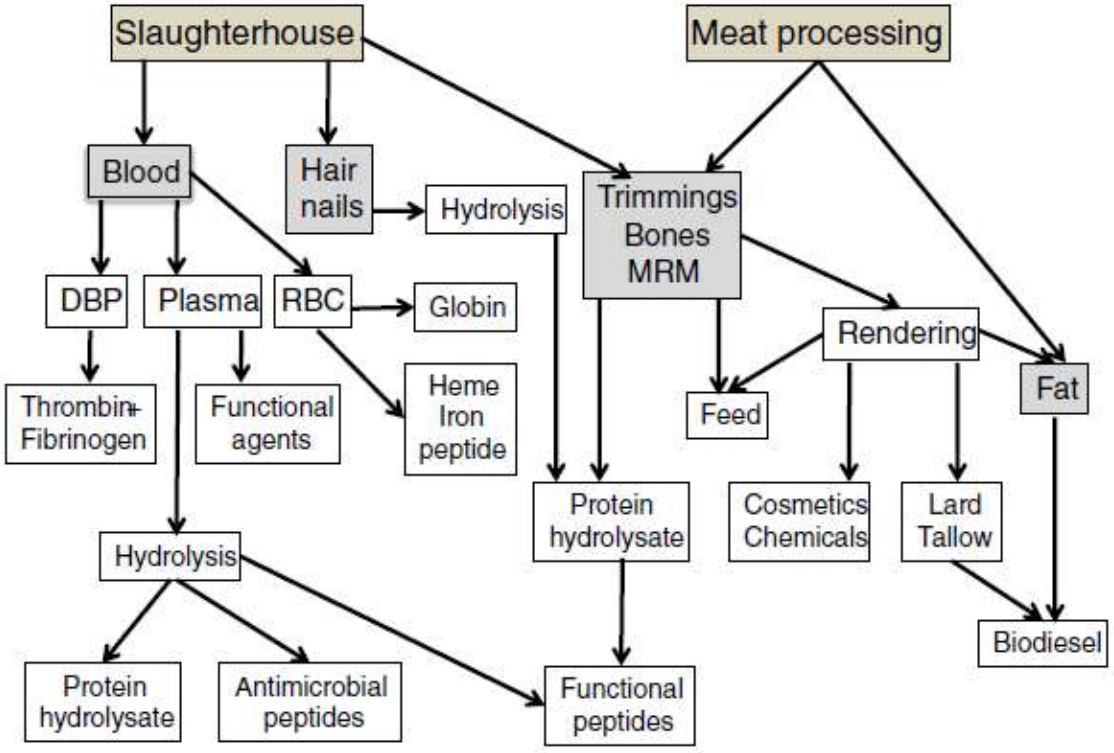

Fig. 1. Flow diagram of main routes for value-addition to meat by-products.

(Source: Toldrá, F., Aristoy, M. C., Mora, L., & Reig, M., 2012)

3.2. Proteins: generation of bioactive peptides

The proteolytic activity during meat processing generates a large amount of peptides and free amino acids through proteolysis mechanisms. Endogenous muscle enzymes like calpains and cathepsins in a first stage followed by the action of peptidyl

peptidases are responsible for such proteolysis. Apart from the endogenous generation, peptides can also be industrially obtained from meat protein wastes (trimmings, organs, collagen, hemoglobin) through hydrolysis with specific commercial proteases like papain, bromelain, thermolysine, pronase or proteinase K. The enzymatic reaction can take place either in a batch-fed reactor or in a continuous way using an ultrafiltration membrane reactor. The product is then submitted to fractionation and partial purification either by filtration or chromatographic techniques. A scheme for such industrial production is shown in Figure 2. Hundreds of peptides are released but only a few, known as bioactive peptides, are of interest because they are able to exert a determined health benefit to the consumer through different types of bioactivity like antihypertensive activity, antioxidant activity or opioid activity among others. The inhibition of the angiotensin I-converting enzyme (ACE) probably constitutes the most relevant bioactivity. This enzyme participates in the renin–angiotensin system where angiotensin I is converted into angiotensin II that constricts the arteries and, as a consequence, increases the blood pressure. An effective way to reduce blood pressure is through the inhibition of ACE. It has been reported that the bioactivity intensity is inversely correlated to the peptide length. Therefore, the peptides that can inhibit ACE in vitro and further exert antihypertensive effect in vivo have shown great promise in the development of a novel therapeutics and functional food for preventing hypertension.

3.3. Protein: generation of antimicrobial peptides

The first identification of a peptide in bovine hemoglobin with antibacterial activity corresponded to the fragment 33–61 of the α-chain of bovine hemoglobin (Fogac et al., 1999). Such peptide was active against Gram-positive bacteria and fungus isolated from the hemolymph of a tick parasitizing the bovines (*Boophilus microplus*).

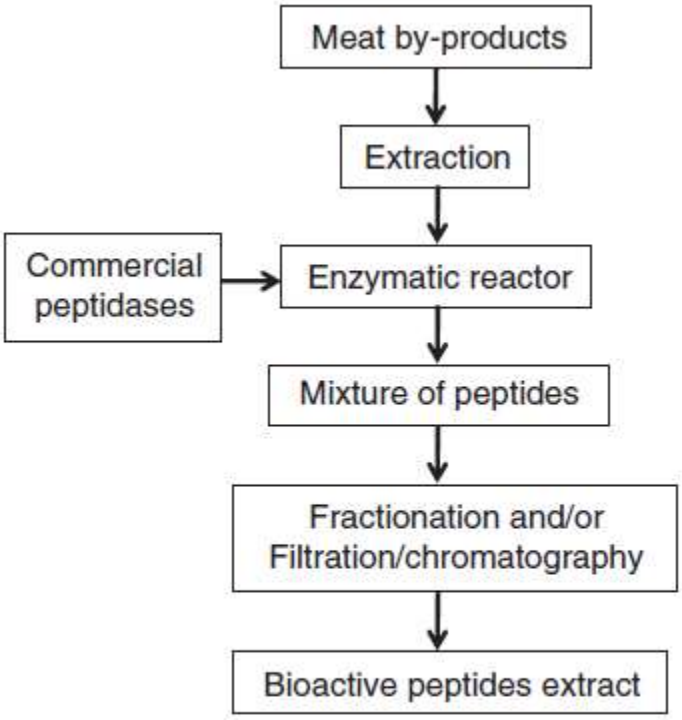

Fig. 2. Flow diagram of the enzymatic hydrolysis of edible meat by-products for the generation of bioactive peptides.

3.4. **Proteins: protein based foams and flavouring agent**

Proteins recovered from the animal rendering process (e.g., blood meal, bone meal or meat) are used to produce protein based foams. These foams are derived from hydrolyzed proteins with the objective to obtain a product with improved physical properties (e.g., reduced surface tension, increased foamability and foam stability). In other cases, hydrolyzed proteins, either chemically or enzymatically, are used as flavor ingredients because they contain small peptides and free amino acids with flavouring properties. These hydrolysates may also react with reducing sugars to generate relevant flavours.

3.5. **Feed and pet food applications**

One of the traditional uses of raw and rendered animal byproducts has been its incorporation as ingredients in feeds and pet foods. These materials provide diets with adequate nutrients and good digestibility. In fact, meat and bone meal, blood meal, plasma meal, hydrolyzed feather meal, tallow or grease contain protein, fat, minerals and trace elements as well as B vitamins and some fat soluble vitamins which are required in animal nutrition.

Different methods for recovering nutrients from animal byproducts and its use as ingredient in feeds have been reported. Some examples are the separation of protein from the animal byproduct materials and drying the meal, the production of high-

quality amino acid solution from the blood of harvested animals through the use of specific microbial cultures or the generation of crude protein extracts from keratin, a fibrous structural protein that constitute structural component of hair, nail, feather and outer layer of skin, through enzymatic hydrolysis with keratinase.

3.6. Other non-food, non-feed industrial applications

Rendered fat has expanded its use for a variety of cosmetic applications like hand and body lotions, creams and bath products. Fatty acids are used in a large amount of chemical processes like rubber and plastic polymerization, softeners, lubricants and plasticizers. Collagen, gelatin and glycerin are also used as ingredients for surfactants, paints, varnishes, adhesives, antifreeze, cleaners, polishes and pharmaceuticals. In recent years, low cost vegetable and animal fat wastes were used as raw materials for biodiesel production, replacing conventional diesel fuel by fatty acid methyl esters. Biodiesel can be a valid alternative to diesel fuel with non significant modifications to the vehicle engines.

3.7. Production of gelatin

Gelatin is a water-soluble animal protein produced through the hydrolysis of collagen. Gelatin is rich in glycine and proline but poor in tryptophan and methionine. Gelatin has good gel-forming ability that makes it of interest in the food industry for a wide variety of applications like desserts, candies, bakery, jellied meat, ice cream and dairy products. Collagen is quite abundant in the carcass and can be extracted from the animal skin, bones, tendons and ossein. The extraction of gelatin follows a four stage process consisting of the selection of the collagen content in the raw material, the removal of noncollagen materials, the controlled hydrolysis of collagen into gelatin and finally the recovery and drying of gelatin. Typical food industry applications of gelatin are found in bakery, dairy and meat products as clarifying agent, stabilizer or protective coating material.

3.7.1 Preparation of skin for gelatin production

Initially, skin should be washed with running tap water to remove dirt, blood and other materials adhering to it. The subcutaneous fat is to be removed by scraping. The skin should be washed thoroughly and stored at -20 °C until further gelatin extraction. It should be thawed overnight at 4 °C before being used.

3.7.2 Process of gelatin extraction

The non-collagenous materials will be removed by treating the skin with 0.1 M NaOH (w/v) solution at a skin/solution ratio of 1:5 (w/v) stirred at room temperature (25±1 °C) for 6 h, and solution will be changed at every 2 h interval (Figure 4). After this, the hairs on the skin will be removed by scraping with scalpel and cut into 1 cm x 2 cm size. Distilled water would be used to wash the skin thoroughly.

Thereupon, the skin would be soaked in 1% HCl at a ratio of 1:10 (w/v) for 20 h with discontinuous stirring at room temperature for swelling. After completion of this process, the samples should be washed thoroughly with distilled water. Thereafter, gelatin is extracted in water bath maintained at 60 °C for 6 h with continuous stirring. The mixture so obtained is passed through cheese cloth and subsequently clarified by centrifugation carried out for 20 min at 12,800 x g. Finally, gelatin was obtained by freeze/oven drying the resulting supernatant.

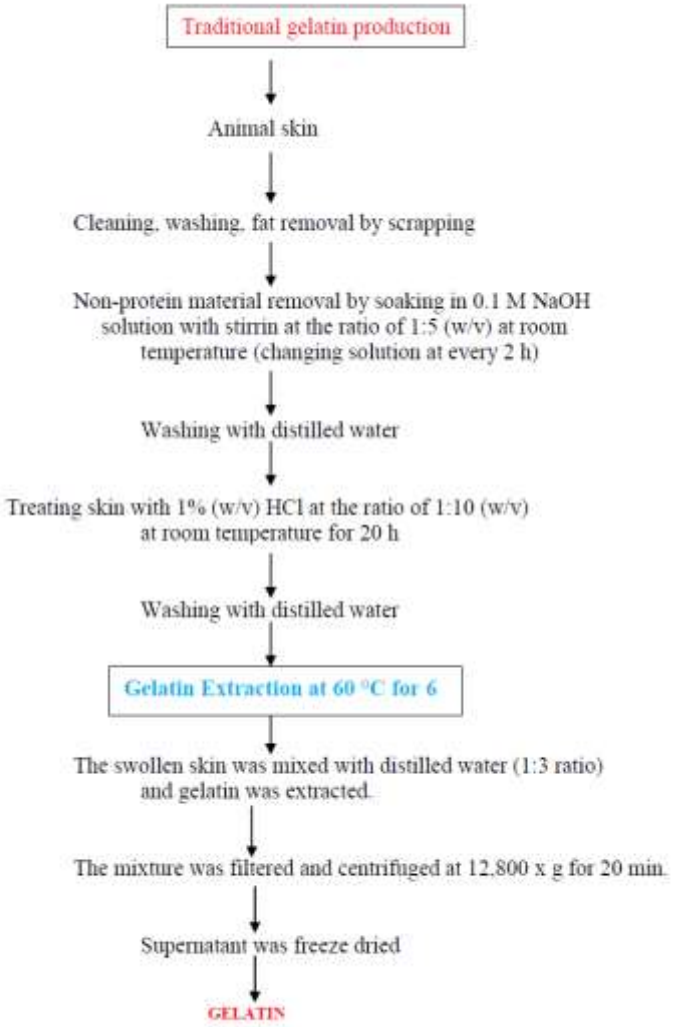

Figure 4: Flow chart of gelatin extraction (traditional method)

****References can be requested from the authors****

Chapter-16

Development of Designer Egg Products for Nutritional and Health Benefits

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1. Introduction

The Indian poultry industry can be broadly classified into two sub-sectors: the highly organized commercial sector accounts for approximately 80% of the total market share, while the unorganized sector accounts for 20% of the total. The unorganized sector, sometimes known as backyard chicken, is crucial to the poorest of the poor's ability to generate additional revenue and provide for their families. According to 20th livestock census total Poultry in India is 851.81 million in 2019, increased by 16.8% over previous Census. India ranks 3rd for egg production in the world. The total egg production in the country is 138.38 billion numbers during 2022-23 (FAO,2023). The total egg production from commercial poultry is 118.16 billion numbers and backyard poultry are 20.20 billion numbers contributing 85.40% and 14.60% of total production of egg respectively. The egg production has increased by 6.77% as compared to previous year (2021-22). The per capita availability was 68 eggs per annum during the period 2016-17 and has been steady increase in per capita availability of egg reaching at 101 eggs per annum in the year 2022-23 (BAHS, 2023). The per capita egg consumption is not increased quantitatively and qualitatively both through the years because of the high cholesterol level in egg yolk. The poultry products like egg have already gained a healthy image to reduce the prevalence of chronic diseases, attempts have been made to modify poultry products such as eggs by adding health-promoting ingredients or reducing components that are harmful. Designing the nutritional profile of poultry eggs using dietary approaches can improve consumers' health and nutritional status in a simple and cost-effective way. Dietary approaches can be used to design eggs with functional and therapeutic properties, such as supplementing with specific nutrients, herbs, or drugs.

2. Egg composition of a normal egg

The average egg has 74 % water, 13 % protein, 11 % fat, 1 % carbohydrates, and tiny amounts of minerals, vitamins, and carotenoids. The eggs macrostructure is composed of 9-12 % shell, 60 % albumen, and 30-33 % yolk. Yolk contains approximately 33 % lipids, including 63.3 % triacylglycerols, 29.7 % phospholipids (73 % phosphatidylcholine, 15 % phosphatidylethanolamine), and 5.2 % total cholesterol (Parmar *et al.,* 2022). In a whole, raw and freshly laid egg, water, protein, fat,

carbohydrates and ash represent about 76.1 %, 12.6 %, 9.5 %, 0.7 % and 1.1 %, respectively (Godbert *et al.*, 2019).

3. History of designer eggs

Cruickshank (1934) was among the first researchers to document the potential to alter the nutritional composition of eggs. In the late 1980s, Sim, Jiang, and their associates worked together produced the 'Professor Sim's Designer Egg', which is high in n-3 fatty acids and antioxidants. The egg was patented In 1997, Van Elswyk created eggs enhanced with conjugated linoleic acid. In Australia, eggs were fortified with folic acid and iron. Other available designer eggs in the market include eggs enriched with vitamins. Leeson and Caston (2004) created lutein and selenium-enriched eggs in Canada that aid in the prevention of eye conditions. Herbal enriched designer eggs (HEDE) have also been developed in India by Narahari (2005). These eggs are rich in carotenoids, n-3 PUFA, selenium, trace minerals, and vitamin E, but they are also enhanced with a variety of herbal active principles that are added to the diets of hens, including allicin, betaine, eugenol, lumichrome, lumiflavin, lutein, sulforaphane, taurine, and many others. Additionally, these eggs have naturally occurring sterols (phytosterols) that are beneficial to the heart, such as β-sitosterol, brassicasterol, campesterol, stigmasterol, and others.

4. Designer egg

"Designer eggs" are those in which the contents have been altered from those of a standard egg. Producing designer eggs involves providing laying hens with a specific diet high in specific vitamins and other nutrients. The special diet consists of canola oil, marigold extract, kelp, and flax seeds (Manohar *et al.*, 2015). Designer eggs are classified as nutritionally enhanced, value added and added processing.

Factors to consider before enhancing egg quality

1. Efficiency of nutrient transfer from feed to the egg
2. Possible toxic effects of nutrients for the laying hens
3. Amount of nutrient delivered with an egg in comparison with recommended dietary allowance (RDA)
4. Established health promoting properties of nutrient and shortage in their diet
5. Possible interactions with assimilations of other nutrients from the egg
6. Stability during cooking
7. Effect of nutrient enrichment on appearance and taste possibilities to claim health benefits

Designer foods obtained from animals are created by either giving them certain diets or by utilizing cutting-edge technology like genetic engineering and cross-breeding (Alagawany *et al.*, 2018). Designer eggs are a well-liked type of Nutri-functional food in the food industry. With the chicken industry developing at a rapid pace, interest in using poultry biotechnology to enhance the genetic and nutritional makeup of eggs for human health is rising. Designer eggs are immune-boosting,

speciality or organic breakfast and lunch with rich in vitamins, minerals, balanced omega-6:3 FA ratio, low cholesterol, high IgG and vital pigment like Flavonoids. Now a day for humans, eggs remain a healthy, highly nutritious with a high nutritional content and quality. Eggs are one of the most popular foods in worldwide because of its nutritious profile, variety, and low cost as a foodstuff. In human diet phospholipids and fatty acids (saturated) are all major contributed through only by animal products (Eaton, 1992). Polyunsaturated fatty acids, or PUFAs, were found to have distinct regulatory roles in the synthesis of several physiologically active compounds, including eicosanoids. Two of the most important PUFA in the current diet are n-6 and omega-6 (FA). Dietary consumption is the only way to get these PUFAs (Cabrera *et al.,* 2011). The incompatibility of PUFA (polyunsaturated fatty acids) (n-3 and n-6) in the human body affects the formation of eicosanoid and intercellular communication (Surai, 2001). By elongating and desaturating LA and ALA, arachidonic acid (20:4n-6), eicosapentaenoic acid (EPA; 20:5n-3), and docosahexaenoic acid (DHA; 22:6n-3) can be produced (Gregory *et al.,* 2011). Many physiological responses in the human body are hypothesised to be influenced by the absolute level and equilibrium of n-6 and n-3 PUFAs in the diet.

The distinctive characteristics of designer eggs

4.1. **High vitamin content:** Higher concentrations of several vitamins particularly vitamin A and E can be achieved in designer eggs. Vitamin A (60–80%), vitamin B12, riboflavin, biotin, and pantothenic acid (40–50%), vitamin D3, and vitamin E (15–25%) have the highest levels. So, the attention should be there for the economic production of high vitamin eggs.

4.2. **Fat and fatty acid profile:** Although changing the total fat content in poultry diets does not significantly alter the overall fat content in eggs, it is possible to modify the fatty acid profile of eggs by adjusting the type of fat in the poultry's diet. Various studies suggest that a high intake of Polyunsaturated Fatty Acids (PUFA) in human diets promotes infant health and reduces the risk of atherosclerosis, heart attack, and stroke. The inclusion of safflower oil, marine algae, fish oil (Shimizu *et al.,* 2001) fish meal, and vegetable oil in poultry feed can increase the omega-3 fatty acid content in egg yolks, which is a vital nutrient for both adults and children. The beneficial effects of omega-3 fatty acids include faster brain development and improved cognitive function, a reduced risk of heart attacks, better oxygen delivery to tissues, and support in managing rheumatoid arthritis, inflammatory disorders, and other diseases. Additionally, a high omega-3 content enhances the keeping quality and shelf life of eggs. Feeding the hens with canola oil results in lower saturated and

unsaturated fatty acid ratio (Parmar *et al.,* 2022). Commercial eggs are high in n-6 PUFAs but low in n-3 fatty acids. Therefore, the focus of designer egg production is on increasing n-3 fatty acids in egg lipids. There are two main approaches to producing n-3 enriched eggs. The simplest method involves increasing linolenic acid, which is a precursor to DHA, by adding flax seeds, linseeds, or their oils to the hen's diet. This diet change enriches the egg yolk with linolenic acid and also boosts DHA levels. Generally, a higher intake of α-linolenic acid helps protect against fatal ischemic heart disease.

4.3. **Omega 3 fatty acid enrichment:** Omega-3 fatty acids, known as n-3 fatty acids, represent a group of polyunsaturated fatty acids characterized by the presence of the first C-C double bond at the third carbon position when counted from the omega end of the carbon chain. Important omega-3 fatty acids include docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), which are primarily sourced from fish oils, as well as α-linolenic acid (LNA), which is obtained from plant oils. he marine-derived ω-3 polyunsaturated fatty acids (PUFAs), specifically DHA and EPA, are predominantly found in deep-sea cold-water fish such as salmon, mackerel, herring, tuna, bluefish, and anchovies, as well as from fish oil and marine algae. Marine algae serve as a highly effective dietary substitute for other sources of n-3 fatty acids. Notably, Schizochytrium sp. has been commercially utilized as an alternative source of omega-3 fatty acids. Marine algae contain approximately 11.2% long-chain n-3 fatty acids on a dry matter basis (Manohar *et al.,* 2015). In comparison, the PUFAs derived from marine algae exhibit greater stability and bioactivity than those obtained from terrestrial plants. Carotenoids present in marine algae may improve the oxidative stability of eggs enriched with n-3 fatty acids (Mudului *et al.,* 2018). The ω-3 fatty acid recommendation to achieve nutritional adequacy is 0.6–1.2% of energy for LNA with a maximum of 10% of this amount potentially coming from EPA or DHA. For the purpose of reducing the risk of cardiovascular disease, a daily dietary intake of 500 mg of EPA and DHA is recommended. Omega-3 eggs represent the initial outcome of altering the composition of eggs, enhanced with nutrients such as choline, conjugated linoleic acid, lutein, selenium, and vitamins B, D, E, and K. This innovative product has garnered significant interest in the context of egg nutrition. Canola oil is frequently utilized to modify the balance between saturated and unsaturated fatty acids. Tampa Farm Servicesoffers an egg that

reportedly has 25% less saturated fat compared to conventional eggs (Mudului *et al.*, 2018).

4.4. **Alteration in pigment content:** Yolk colour is an indicator of the pigment content in eggs and can vary based on dietary

supplements such as plants like marigold, chili, or corn, as well as blue-green algae like spirulina. Recent studies have shown that a high intake of carotenoids can reduce macular degeneration, a leading cause of blindness in the elderly (Parmar *et al.*, 2022). Most of the natural pigment sources like carotenes, xanthophyll, cryptoxanthin, zeaxanthin, lutein present in alfalfa, corn gluten meal, blue green algae - spirulina, marigold petal meal and capsicum are used in feeds at 1-5 % levels to increase the yolk colour and adding 0.5 kg of turmeric powder and 1 kg of red chili powder per ton of feed not only enhances yolk colour but also serves as an antimicrobial and antioxidant. Pigment enrichment in the yolk shows beneficial effects like preventing muscular degeneration and acts as anti-carcinogenic agent. Adding marigold as a feed supplement for desi birds in a semi-range system helps enrich carotenoid pigments in egg yolks, improving their colour, which is preferred by health-conscious consumers (Sujatha *et al.*, 2015). Feeding hens with natural colorants like paprika results in more yellow yolks (Saleh *et al.*, 2021). This highlights the importance of egg yolk colour as a key factor in consumer preference.

4.5. **High mineral content:** Most minerals, particularly calcium and phosphorus, are concentrated in the eggshell, making it difficult to alter their levels in the edible parts of the egg (albumin and yolk). Scientists have successfully increased the content of certain microminerals especially selenium, iodine,

zinc, copper, and chromium, through dietary supplementation. Iodine deficiency is prevalent in many developing countries, including India, so eggs could serve as an excellent source for iodine supplementation. The selenium content in eggs can also be enhanced by incorporating selenium yeast into the hens diet. Supplementing with zinc sulphate (75 mg/kg) in the hens diet effectively increases the zinc content in eggs (Megha *et al.,* 2021). Adding iodine at 6.50 ppm to the layer diet is a cost-effective way to produce iodine-enriched eggs, compared to using 3.25 ppm (Sumaiya *et al.,* 2016). Including 0.4 ppm selenium as selenomethionine in the feed can provide 50 % of the recommended daily allowance for selenium in one egg (Yaroshenko *et al.,* 2003; Surai, 2001)

4.6. **Pharmaceutical alterations:** Advancements in biotechnology now allow us to produce genetically modified chickens that can lay eggs containing specific desired compounds. Hens produce antibodies to neutralize the antigens (such as viruses and bacteria) and are passed into the eggs to protect the developing chick. Immunologists are utilizing the hens ability to produce antibodies against a wide range of antigens and concentrate them in the eggs, so that hens can develop targeted antibodies by injecting specific antigens. With the advancements in biotechnology, future designer eggs could be created to contain antibodies for treating everything from snake venom to microorganisms that cause tooth decay.

4.7. **Low cholesterol:** An average-sized egg contains approximately 200-220 mg of cholesterol. Numerous researchers have attempted to reduce the cholesterol content in chicken eggs through genetic, nutritional, or pharmacological interventions. Studies have shown that supplementing laying hen diets with chromium at concentrations below 1 ppm can lower egg cholesterol and improve egg quality. Low-cholesterol eggs can also be produced by feeding hens an all-vegetarian diet rich in protein and fibre, fortified with vitamin E (Manohar *et al.,* 2015). Designer diets enriched with omega-3 fatty acids and natural antioxidants given to White Leghorn hens significantly reduced yolk cholesterol levels ($p<0.01$) while increasing omega-3 fatty acids in the eggs (Sujatha and Narahari, 2011). Eggs from hens fed with 10% menhaden fish had 13.6 % less cholesterol in the yolk and similarly feeding hens a diet with 1.5 % menhaden fish oil or 5 % flaxseed (whole or ground) reduced yolk cholesterol by about 9 % (Parmar *et al.,* 2022). Supplementation of Lactobacillus

acidophilus (LA) to ration of laying hens resulted in decrease yolk cholesterol (Alaqil et al., 2020). Supplementing the flaxseed meal or mixture with rapeseed meal or rice bran up to 10% of feed in the diet of poultry will help in reduction of yolk cholesterol (Panaite *et al.*, 2020)

4.8. **Biological compounds:** Chicken can produce antibodies that neutralize antigens from bacteria, viruses, and other pathogens. These antibodies circulate in the blood and are transferred to the eggs to protect the chicks. Researchers are exploring this capability, aiming to develop eggs that contain antibodies targeted against a wide range of antigens. In the future, we may see designer eggs containing specific antibodies, such as anti-venom against snake bites.

4.9. **Shell colour:** Regional consumer preferences influence eggshell colour, with about half of the designer eggs on the market having brown shells. A brown-shelled egg is considered a designer egg because it stands out from the conventional market. In some countries, there is demand for even blue-shelled eggs

4.10. **Antioxidants enrichment in eggs:** Poultry eggs are naturally rich in antioxidants like vitamin E, selenium, carotenoids, flavonoids, lecithin, and phosvitin, which help protect against oxidative rancidity during storage. However, eggs are still prone to spoilage. Designer eggs not only have high levels of these natural antioxidants but also include synthetic antioxidants like Ethoxyquin and herbal antioxidants such as Carnosine, Curcumin, Lycopene, Quercetin, and Sulforaphane, depending on the herbs added to the poultry diet (Narahari, 2005). Adding these antioxidants to the feed is important to extend the shelf life of the eggs. Enrichment of eggs with numerous advantages like decreasing susceptibility to lipid peroxidation, prevention fishy odour to the product, prevents destruction of fat-soluble vitamins, prevents denaturation of natural fat-soluble pigments. Vitamin E and organic selenium can be added as anti-oxidants at levels of 200- 400mg/kg and 0.1-0.3ppm for designer egg production (Parmar *et al.*, 2022)

4.11. **Immunomodulating egg production:** Eggs naturally contain compounds like lysozyme, G1-globulin, G2 and G3 globulin, and antibodies, which have antimicrobial and immune-boosting properties. These globulin antibodies can

be helpful in treating immunosuppressed patients, such as those with AIDS. Chicken eggs are rich in antibodies like IgY, which are more cost-effective and efficient than mammalian IgG. In six weeks, a hen can produce around 298 mg of specific antibodies, which can be used to treat infections like human rotavirus, E. coli, Streptococcus, Pseudomonas, Staphylococcus, and Salmonella. The IgY levels in eggs can be increased through dietary changes. Feeding chickens with diets rich in omega-3 fatty acids and antioxidants can boost IgY levels in eggs. Herbal supplements, particularly Basil leaves (Tulasi) at 0.3-0.5% of the diet, are highly effective in increasing IgY levels. Other herbs like Rosemary, Turmeric, Garlic, Fenugreek, Spirulina, Ashwagandha, and Arogyapacha also have immune-boosting properties (Mudului *et al.,* 2018).

4.12. **Herbal enriched eggs:** Phytobiotics, which are products derived from plants and rich in various secondary metabolites, can be incorporated into poultry diets to enhance hen performance and facilitate the production of herbal-enriched super eggs. The feed for chickens can be augmented with a variety of herbs, including garlic and onion leaves, spirulina, basil, turmeric powder, citrus pulp, flaxseed, red pepper, and fenugreek seeds. These super eggs are characterized by lower levels of LDL cholesterol, possess immunomodulatory and antioxidant properties, exhibit anticarcinogenic effects, and are higher in omega-3 fatty acids (Muduli *et al.,* 2018). The eggs developed by Narahari (2005) were abundant in numerous herbal active compounds such as allicin, betaine, eugenol, lumiflavin, lutein, sulforaphane, and taurine, with the specific active principles varying based on the herbs included in the hens diet. Notable health-promoting ingredients included garlic, fenugreek, and bay leaves, with garlic (Allium sativum) exhibiting potential benefits such as lowering lipid levels, reducing blood pressure, managing blood sugar, preventing blood clots, minimizing atherogenic effects, and promoting lactation.

Table 1. The presence of active compounds in herbal-infused designer eggs and their implications for human health

Herbs	**Active principle ingredients**	**Benefits**
Fenugreek, spices	Quercitin, Luteolin, Diosgenin, citogenin	Promotes the release of insulin and exhibits antimicrobial properties
Bay (curry) leaves, Marigold petals	Lutein	Antioxidant, improve vision

Garlic, onion and their leaves	Allicin, Allylic sulfide	Lower LDL cholesterol as well as anticarcinogenic properties
Turmeric powder	Flavonoid components	Antimicrobial as well as antioxidant
Spirulina, marigold petals, alfa-alfa, red pepper	Carotenoid pigments	Antioxidant and anticarcinogenic
Flax seed, canola fish, oil insects, worms	ω-3 PUFA	Decrease LDL cholesterol, hypertension, angina and atherosclerosis
Sugar beet, grape pulp	Betaine	Decrease plasma homocysyeine, which ruptures arterial walls

(Satapathy et al., 2017)

Table 2. The table presents the nutrient composition and the corresponding quantities found in 100 grams of egg contents (Ordinary and Designer egg)

Nutrient content	**Ordinary egg**	**Designer egg**
Total saturated fatty acids	3.3g	2.8g
Total unsaturated fatty acids	6.4g	6.9g
MUFA	4.4g	4.4g
PUFA	2g	2.5g
ω-3 fatty acid	0.03g	0.7g
ω-6 fatty acid	1.9	1.4
ω-6 /ω-3 ratio	17.3	1.27
EPA+ DHA	0.08g	0.4g
Cholesterol	400mg	320mg
Carotenoids	1.5mg	2.5mg
Vitamin E	2mg	15mg
Selenium	Traces	1.8µg
Chromium	Traces	1µg

(Parmar et al., 2022)

5. Conclusion

Designer eggs present an alternative for consumers seeking eggs that offer enhanced nutritional benefits specific health benefits that differ from standard eggs. The emergence of designer eggs significantly broadens the scope of functional foods aimed at promoting **human** health. By altering the hens diets with specific ingredients such as seed oils, marine algae, vitamins, and minerals, it is possible to reduce cholesterol levels in eggs while simultaneously increasing their omega-3 fatty acid content. Additionally, a diet enriched with vitamins and

minerals elevates the levels of micronutrients and antioxidants found in eggs. The incorporation of functional feeds and herbs **further** enhances the nutraceutical value and visual appeal of the eggs. While conventional shell eggs serve as a nutrient-dense, high-quality, and cost-effective source of protein along with essential vitamins and minerals, the strategic feeding of hens can yield eggs that provide additional health benefits beyond their already impressive nutritional profile. Consequently, value-added and health-promoting egg products can be made accessible to consumers who prioritize health. However, the design process must carefully consider various factors, including production facilities, available resources, technical expertise, economic constraints, and the environmental and welfare implications associated with egg production.

6. Future perspectives

There is a significant demand for designer eggs that possess innovative functional properties, however, the commercial production of these products is still hindered by a lack of expertise. To facilitate the successful marketing and production of this new generation of eggs and egg-based products, further research is essential. Additionally, it is important to conduct more studies focused on enhancing the quality of designer eggs and evaluating the long-term health effects associated with their consumption, ultimately aiming to persuade consumers of the advantages of incorporating these eggs into their diets.

****References can be requested from the authors****

Chapter-17

Strategies for the development of new value-added animal food product

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1. Introduction

The evolution of the global food market necessitates the development of new value-added animal food products to address diverse and dynamic consumer demands. With the world's population projected to approach 9.8 billion by 2050 and food demand expected to rise by 70%, there is a critical imperative to enhance and innovate animal food production systems (FAO, 2020). The projected surge in meat production, anticipated to reach 200 million tonnes by mid-century, underscores the urgency of advancing strategies that enhance the value of animal-based products while simultaneously addressing environmental and economic challenges (OECD-FAO, 2021). Consumers preferences are shifting towards products that offer health benefits, convenience and environmental sustainability. To remain competitive, the animal food sector must embrace innovations that cater to these evolving demands.

Key strategies for developing value-added animal food products encompass several core areas including product innovation, market research, technological advancements, sustainability practices and regulatory compliance. Product innovation plays a crucial role in meeting nutritional needs, enhancing health benefits and addressing specific dietary preferences (Vieira et al., 2021). Market research is essential for identifying trends and consumer demands, which drives the development of effective products. Technological advancements, such as high-pressure processing and advanced packaging, have significantly improved product quality and shelf life (Nabi et al., 2021). As health consciousness and sustainability concerns grow, there is an increased demand for functional foods and eco-friendly practices (Moons et al., 2018). Additionally, regulatory compliance ensures safety and quality through transparent labeling and adherence to food safety regulations. By integrating these strategies; product innovation, market insights, technological advancements, sustainability practices and regulatory adherence, the industry can effectively address consumer demands, enhance profitability and contribute to sustainable food production.

2. **Product Innovation**

Product innovation is the cornerstone of developing new value-added animal food products. It involves identifying gaps in the market and creating products that offer unique benefits to consumers. The innovation process can take various forms:

- ***Nutritional Enhancement****:* With growing awareness of health and wellness, there is an increasing demand for animal food products with enhanced nutritional profiles. This includes fortifying meat, dairy, and other animal products with vitamins, minerals and other beneficial compounds. For example, omega-3-enriched eggs and probiotic-enhanced dairy products cater to health-conscious consumers (Henchion et al., 2021).
- ***Functional Foods****:* Functional foods, that provide health benefits beyond basic nutrition, represent a significant opportunity. Incorporating bioactive compounds such as antioxidants, prebiotics and probiotics into animal food products can add value and appeal to a broader market segment (Gul et al., 2016).

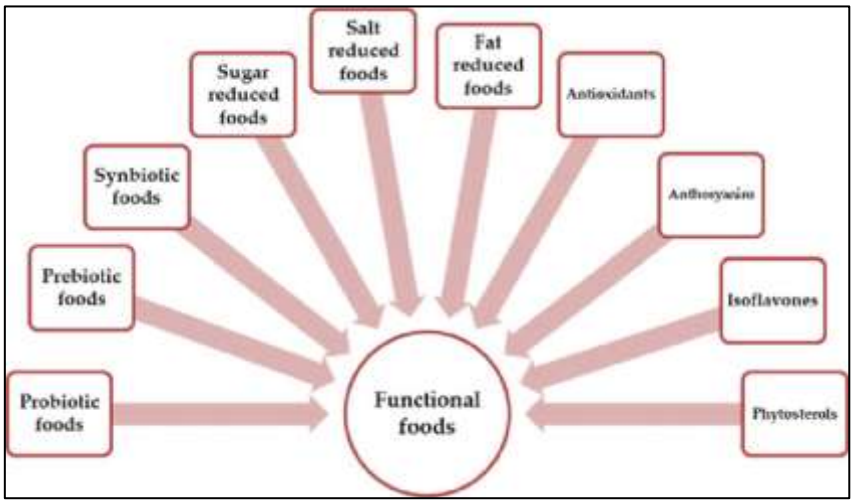

Fig. 1. Different types of functional foods

- ***Convenience Products****:* The demand for convenience foods is on the rise, driven by busy lifestyles. Developing ready-to-eat or easy-to-prepare animal food products, such as pre-cooked meals, snack-sized portions and microwaveable options, can attract time-pressed consumers (Aviles et al., 2020).

3. **Market Research and Consumer Insights**

Understanding consumer preferences and market trends is essential for successful product development. Comprehensive market research helps identify target demographics, assess consumer needs and evaluate competitors. Key steps in this process include:

- ***Consumer Surveys and Focus Groups****:* Conducting surveys and focus groups allows for direct feedback from potential customers. This information can

guide the development of products that align with consumer expectations and preferences.

- ***Trend Analysis:*** Monitoring industry trends, such as the rise of plant-based diets or the growing interest in ethical and sustainable food production, can inform the direction of product development. Staying ahead of these trends enables companies to capitalize on emerging opportunities.
- ***Competitor Analysis:*** Evaluating the strengths and weaknesses of existing products in the market provides insights into how new products can differentiate themselves. This analysis can reveal gaps that new products can fill or areas where innovation can offer a competitive advantage.

4. Technological Advancements

Leveraging technological advancements is crucial for the efficient and effective development of value-added animal food products. Technology can enhance various aspects of the production process, from improving product quality to extending shelf life.

- ***Processing Technologies:*** Advanced processing techniques, such as high-pressure processing (HPP), pulsed electric field (PEF) technology and ultrasound, can improve the safety, texture and nutritional quality of animal food products. These technologies help retain more nutrients and reduce the need for preservatives, appealing to health-conscious consumers (Pou, 2021).
- ***Packaging Innovations:*** Innovative packaging solutions, such as vacuum packaging, modified atmosphere packaging (MAP) and active packaging, can extend the shelf life of animal products while maintaining their freshness and quality. Sustainable packaging options also align with the increasing consumer demand for eco-friendly products (Kandeepan et al., 2022).
- ***Digital Technologies:*** The integration of digital technologies, such as blockchain and IoT (Internet of Things), can enhance traceability and transparency in the supply chain. Consumers are increasingly interested in the origin and production practices of their food, and digital solutions can provide the necessary information to build trust and loyalty (Alamsyah et al., 2022).

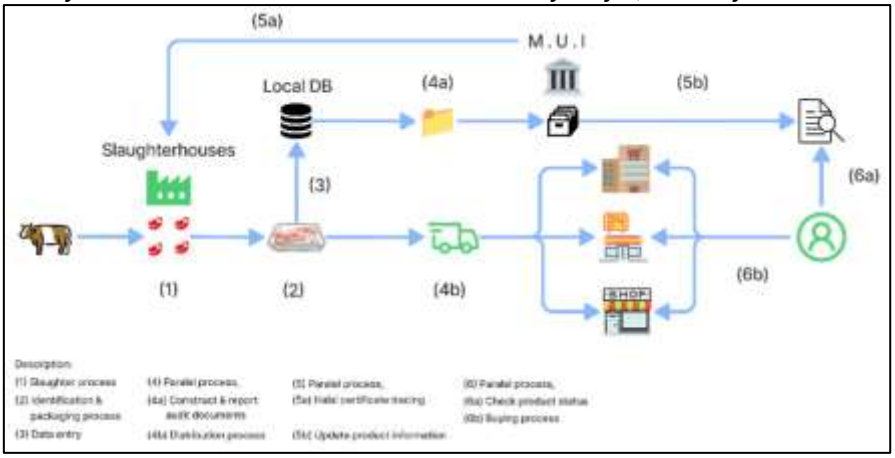

Fig. 2. Blockchain-Based Traceability System (*Source: Alamsyah et al., 2022*)

5. Sustainability and Ethical Considerations

Sustainability is a key driver in the development of new animal food products, as consumers and regulatory bodies place greater emphasis on environmental and ethical considerations. Strategies to enhance sustainability include:

- ***Resource Efficiency****:* Implementing practices that reduce waste and optimize resource use is critical. For example, using by-products from meat processing to create new products, such as bone broth or pet food, can add value while minimizing waste (Toldrá et al., 2021).
- ***Sustainable Sourcing****:* Ensuring that raw materials are sourced sustainably is increasingly important to consumers. This can involve working with suppliers who adhere to sustainable farming practices, such as those that prioritize animal welfare, reduce greenhouse gas emissions and minimize water usage.
- ***Eco-friendly Packaging****:* Developing packaging that is biodegradable, recyclable or made from renewable resources can enhance the sustainability of animal food products. This not only reduces the environmental impact but also appeals to environmentally conscious consumers (Khodaei et al., 2021).

6. Regulatory Compliance and Quality Assurance

Navigating the regulatory landscape is essential for bringing new animal food products to market. Ensuring compliance with food safety standards and quality assurance protocols is critical to maintaining consumer trust and avoiding legal issues.

- ***Compliance with Food Safety Regulations****:* Adhering to national and international food safety regulations, such as those set by the FDA, EFSA and other regulatory bodies is crucial. This includes meeting standards for ingredients, processing methods, labeling and packaging (FAO, 2020).
- ***Quality Assurance Programs****:* Implementing robust quality assurance programs ensures that products consistently meet safety and quality standards. This can involve regular testing, audits and certifications, such as ISO 22000 or HACCP, which demonstrate a commitment to food safety (Chen et al., 2020).
- ***Transparency and Labeling****:* Clear and accurate labeling is essential for meeting consumer expectations and regulatory requirements. Labels should provide information on nutritional content, ingredients and any claims made about the product, such as organic or non-GMO status (Codex Alimentarius, 2018).

7. Conclusion

The development of new value-added animal food products requires a multifaceted approach that combines innovation, market research, technological advancements, sustainability and regulatory compliance. By focusing on these

strategies, producers can create products that meet consumer demands, enhance profitability and contribute to a sustainable and ethical food system. As the industry continues to evolve, staying ahead of trends and leveraging new technologies will be key to maintaining a competitive edge in the market.

****References can be requested from the authors****

Chapter-18

Processing of Meat into Convenience Emulsion based Meat Products

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1. Introduction

A true emulsion is a colloidal mixture where two immiscible liquids—such as oil and water, which don't naturally mix—are combined. Usually, a non-polar liquid is dispersed within a polar liquid. To create a stable emulsion, a third component called emulsifying agent is needed. This agent works at the boundary between the fat and water to stop the fat from clumping together. Milk is an example of oil-in-water emulsions, where fat droplets are dispersed in an aqueous medium. Conventionally, we call a finely chopped meat mixture a meat emulsion, but this term is somewhat misleading. In reality, what we call a meat emulsion is actually a mixture of solid/liquid fat particles dispersed in a liquid continuous phase consisting of water containing dissolved and suspended salts and protein. Although, meat emulsion could be categorized as oil-in-water emulsion, some fat particles are larger than 50μm in diameter and do not fulfill the requirements of classical emulsion. Therefore, it might be more accurate to refer to this as a meat batter.

The emulsifying agent play a critical role in meat emulsion formation and meat proteins act as the emulsifying agents. In meat emulsions, mainly sarcoplasmic and myofibrillar proteins act as emulsifying agents. However, myofibrillar proteins are more efficient emulsifying agents and contribute to emulsion stability. For the emulsion to be stable, these proteins need to encase the finely chopped fat particles before cooking. The composition of meat proteins can differ based on their amino acid side chains, which may have positively or negatively charged groups and can be either polar (like water) or non-polar (like fat). Myosin, the primary structural protein in meat, plays a crucial role in fat emulsification and the water-holding capacity of processed meats. It is thought that myosin helps in stabilizing the oil-water interface: the non-polar amino acid residues in the myosin tail attract to the fat/oil, while the polar amino acid residues in the myosin head interact with the water phase.

2. Objectives of Preparing Emulsion-Based Meat Products

Efficient Use of Spent Animals: Emulsion-based meat products enable the effective utilization of spent animals and lower value meat cuts with more connective tissue, ensuring that meat from older or less desirable animals/cuts is transformed into high-value products rather than being wasted.

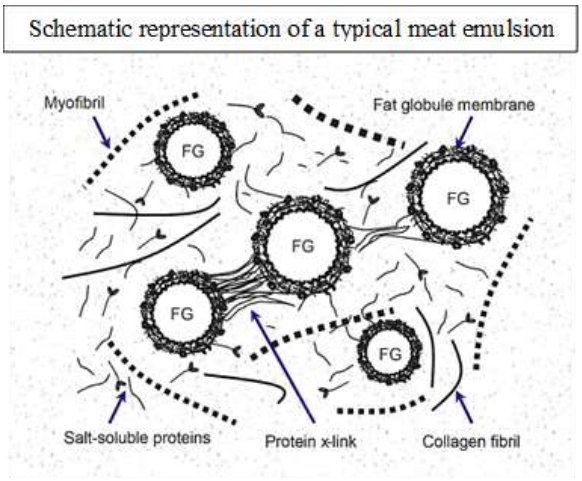
Creation of Diverse Products: Emulsion technology allows for the transformation of meat into a wide range of convenience products with varying tastes, shapes, storage stability and nutritional attributes. This versatility enables the development of unique and diverse meat products tailored to different consumer preferences.

Tenderization of Meat Tissue: The process of mincing and chopping muscle and connective tissue fibers during emulsion preparation helps in tenderization of relatively tough meat. This mechanical action breaks down tough fibers, resulting in a more tender and palatable final product.

Reduction of Moisture and Fat Loss during Cooking: Emulsifying meat helps in retaining moisture and fat during cooking, enhancing key eating quality attributes such as juiciness, texture, flavor, and overall cooking yield. This retention ensures that the final product remains moist and flavorful, enhancing its sensory desirability and demand.

Increased product Volume and Economical products: By incorporating various edible meat byproducts, low-value meat, and non-meat lower cost ingredients such as soya proteins, binders' etc. emulsion-based processes can increase the volume of the final product. This method maximizes the use of available resources, make meat products more economical and affordable for people in lower social strata or lower income.

3. Preparation of meat emulsion



The preparation of meat emulsion involves a precise process to achieve a stable and high-quality product, using lean meat, water, fat, salt and other ingredients including some seasonings. Initially, meat along with salt is finely chopped or ground to break down muscle fibers and connective tissues, extracting soluble proteins suspended in an aqueous medium creating a uniform mixture. The mixture is then emulsified, typically using mechanical action to disperse fat particles within the meat matrix and create a smooth, cohesive blend. Further, binders, flavoring and seasoning ingredients are added. To ensure stability, the emulsion is often chilled with ice to control the temperature and prevent fat from separating. Proper mixing and emulsification are crucial, as they affect the texture, juiciness, and overall quality of the final product. The prepared emulsion is then shaped into desired form and cooked, during which it retains moisture and fat, resulting in a flavorful, juicy and tender meat product.

4. Major factors affecting emulsion stability

Meat emulsification is a scientific process governed by many factors affecting the stability and functionality of meat emulsion. Important factors affecting emulsion stability are enlisted below:

Meat condition at the time of use: Immediately after slaughter, myosin in the muscle is in a readily usable state. However, once rigor mortis sets in, myosin combines with actin to form actomyosin. Although, actomyosin can still bind water and fat, it is less effective than myosin and does not dissolve as easily at the salt concentrations used in meat emulsions.

pH of Meat: One crucial element is pH, which significantly affects both the water-holding and emulsifying capacities of meat. Water-holding capacity (WHC) of meat can be compared to function of a sponge and play a very important role in meat processing; because proteins that can retain more water are more soluble. WHC is lowest at iso-electric point (pI) of proteins and for meat, the pI—and thus the point of minimal WHC—falls within the pH range of 5.0 to 5.4, which corresponds to the pH of meat after rigor mortis. Increasing or decreasing the pH away from the pI will result in increased WHC. Hence in general protein solubility and fat emulsifications increases with increasing pH. Alkaline phosphates exert a significant pH increase and added commonly in processed meat products.

Meat Quality: Meat quality plays a crucial role in emulsion stability by affecting how well the proteins can interact with and bind water and fat. High-quality meat with lower connective tissue and optimal protein structure and functionality ensures better solubility and emulsification, leading to a more stable and homogeneous emulsion. Poor-quality meat, especially from aged animals have compromised protein functionality, which can undermine the emulsion's stability and texture.

Salt Concentration: Optimal brine solution to solubilize myosin is around 7 percent and for meat with 65-70% percent moisture, 4.5 percent salt contact is ideal for maximum protein extraction. This can be achieved during the chopping stage by adding the salt directly to the meat without additional water. Once extracted, these proteins remain soluble when additional water is added.

Fat particle size: Fat emulsification requires reducing fat to a sufficiently small size so that the extracted proteins can coat or encapsulate the fat. If the fat particles are too large, the emulsion will not be smooth or stable. Conversely, if the fat is chopped too finely, the surface area may become too extensive, resulting in inability of meat proteins to coat fat particles and unstable product.

Temperature of Emulsion: Chopping or emulsifying temperatures can significantly impact the stability of meat emulsion. High temperature leads to the breakdown of emulsion. The chopping time has great effect on temperature, hence should be optimized as per the temperature of emulsion which can be maintained by using ice in place of water and maintaining lower room temperature.

5. Requirements

i. Meat (Lean meat/Spent animal meat/low priced cuts/trimmings)
ii. Fat— Animal origin/vegetable oil
iii. Non meat ingredients— Ice/chilled water, alkaline phosphate, Sodium nitrite/nitrate, salt, sugar, spices, condiments (Onion, garlic) and binders
iv. Casings— Natural/synthetic for sausages
v. Packaging material
vi. Equipment— Meat mincer, Bowl chopper, Sausage filler, Meat Slicer, Patty maker, Smoking unit, Cooking utensils etc.
vii. Formulation— as per the available ingredients

6. Procedure to prepare meat emulsion

i. Collect raw materials i.e. meat, fat and other non-meat ingredients and weigh as per the formulation specifications.
ii. Mince the meat and animal origin fat, if utilized, separately using 1/4" and 1/8" grinding plate, respectively.
iii. Transfer the ground meat to bowl chopper and chop minced meat for 1.5-2 minutes, while gradually adding salt. The addition of salt before any other ingredients ensure the contact of meat proteins with higher salt concentration, resulting in better protein extraction.
iv. Add ice flakes (about 10% of the final volume) followed by addition of alkaline phosphate and chop again for 1.5-2 minutes, depending on type of meat.
v. Add ground fat or vegetable oil and chop again for 1-2 minutes, ensuring proper dispersion of fat globules in the batter and coating of fat globules with soluble proteins extracted in the previous steps.
vi. Add remaining ingredients such as binder (refined wheat flour), condiments and spices and continue chopping for another minute to ensure proper distribution of all ingredients in the emulsion.
vii. The completion of emulsification process is indicated by the sticky consistency of batter and batter starts sticking to contact surfaces.
viii. Emulsion formed is shaped into various shapes either manually or mechanically to prepare different products such as sausages, nuggets, meat balls, patties etc.

7. Preparation of emulsion based meat nuggets

i. Rectangular aluminum or stainless steel molds with tightly closing mechanism are filled with a large lump of meat emulsion and pressed evenly to ensure that it fills the mold completely. It's better to use slightly more emulsion than the mold's volume to ensure proper adhesion and avoid air pockets.
ii. Close the mold with the lid tightly while securing the lid properly.

iii. Transfer the filled molds to a steam chamber and cook for 30-40 minutes under steam, ensuring proper circulation of steam for efficient cooking, so that the final product attains to a temperature of 75°C or more.
iv. Remove the molds and rinse with cold water to bring them to room temperature.
v. Place the molds in the refrigerator at 4°C to cool and chill for 4-6 hours.
vi. Remove the cooled meat blocks from the molds and cut into uniform size using meat slicer or a sharp knife.
vii. The product could be packed aerobically or vacuumed packaged depending on shelf-life requirement and stored at -18°C till further use.
viii. Product could be thawed and shallow fried and added to other recipes and per requirement, before consumption.

8. Preparation of emulsion based Sausages

Sausages have a rich history and global significance that spans thousands of years. Originating in ancient civilizations like Babylon and China around 1500 BC, sausages were among the earliest methods of meat preservation, utilizing salt and encasement in animal intestines. This technique allowed for the preservation and portability of meat, crucial for survival and trade in ancient times. In olden days, the sausage mixtures were encased in animal intestines or stomachs and have almost cylindrical shape, characteristics shape of sausages, which is maintained even when synthetic casings are used. Over the centuries, sausages have evolved, adapting to various cultures and cuisines worldwide. Today, they hold significant culinary importance in diverse cultures, from Italian salami and German bratwurst to Mexican chorizo. Beyond their historical and cultural value, sausages play a vital role in modern economies by providing an economical way to utilize various cuts of meat and by-products, while also offering a rich source of protein and essential nutrients.

Procedure for Sausage preparation

i. Stuffing/Filling: The emulsion is transferred to a sausage filler (manual or electrical operated) and emulsion is filled or stuffed into natural (made from animal intestines) or artificial like collagen or cellulose) casings to five them proper cylindrical shape.
ii. Linking/Tying: The stuffed casings are twisted at regular intervals to form individual sausage links of uniform size. Alternatively, casings with emulsion can be tied at defined intervals with a thread also.
iii. Cooking: The stuffed and linked sausages are cooked by using water at a temperature of 80°C for about 20 minutes. Otherwise, sausages are smoked and cooked simultaneously in smoke house or cooked smokes can also be smoked for some time to impart smoky flavor.

iv. Cooling: After cooking or smoking, sausages are cooled rapidly using cold water to prevent bacterial growth and maintain texture. It also helps in easy removal of synthetic casings from the sausages.
v. Packaging: The chilled sausages are packed in to suitable consumer packs by vacuum sealing or aerobic packaging and kept in refrigerator or freezer, till consumption.

9. Preparation of emulsion based Meat patties

i. Place approximately 70-75 grams of emulsion into a circular aluminium or glass mould (75 mm D x 15 mm H). In addition, manual or continuous patty machine could also be used give shape to the patties.
ii. Shape the emulsion in the form patties and arrange them on a perforated tray.
iii. Transfer the trays with the patties into a preheated baking oven or hot air oven or grill set at 180°C and cook for 20 minutes.
iv. After 10-12 minutes of cooking, carefully turn the patties to ensure even cooking on both sides and continuing cooking till internal temperature reaches 75°C.
v. Remove the cooked patties from oven, let them cool down to room temperature and then pack them into suitable packaging. Store patties in refrigerator or at -18°C as per the need.

10. Preparation of emulsion based Meat balls (Kofta)

Meatballs, commonly referred to as "kofta," are a widely consumed dish across the country. Meatballs are typically made from a coarse meat mix or meat emulsion and prepared either manually or with the help of a meatball forming machine. To prepare meat balls take about 20-30g of meat emulsion and shape in the form of ball. Keep the balls in refrigerator for ½ to 1 hour for setting and then cook in hot water (80°C) or steam for about 20 min, till the internal temperature reaches 72°C or more. Alternatively, meat balls can also be fried to prepared fried meat kofta or balls.

11. Precautions to take

vi. Take care to prevent excessive chopping, at it can lead to emulsion breakdown due to the increased surface area of fat droplets.
vii. Assess the quality of the meat, particularly the availability of myofibrillar proteins, before finalizing the formulation.
viii. Accurately weigh all ingredients and add them according to the prescribed steps, ensuring salt is added before the fat.
ix. Maintain a temperature below 70°F (21°C) during chopping. Adding ice flakes or chilled water in stages helps in managing the temperature.
x. Ensure the internal temperature of the product reaches at least 75°C.
xi. Use oil, butter paper, or food-grade PE to make boxes for nuggets or trays for patties non-stick.

xii. Process the meat emulsion immediately; in case of any delay, keep it refrigerated.
xiii. Maintain uniform pressure while filling sausages, in accordance with the strength of the casings.

12. Strategies to improve quality and marketing of emulsion based meat products

Development of economic formulations: To create a range of highly acceptable economical products, a blend of vegetables (rich in fiber) or cereals can be included in the emulsion. Including vegetables in processed products can enhance the nutritional quality by adding fibre. Further, soya proteins could be used to replace the meat protein without compromising the product quality while ensuring the economy of these products.

Addition of edible by-products: Incorporating edible by-products into meat emulsion can enhance both nutritional value and cost-effectiveness ensuring more sustainable production process. Edible by-products like liver, heart, or kidney are rich in vitamins and minerals, contributing to a more nutritionally balanced product. However, while incorporating by-products it is important to ensure proper handling and processing to maintain food safety and quality.

Additional proteins as emulsifiers: The meat with high connective tissue and inadequate myosin level require addition proteins for proper emulsification. Whole eggs liquid or egg white could be added in the formulation with cost and nutrition advantage. Egg protein is superior to meat protein with higher biological value but cheaper in cost hence the advantage. In addition, egg proteins act as good emulsifier. Other proteins like vegetable or milk proteins were successfully incorporated in emulsion based meat products. Blood plasma proteins possess very good functional properties making them highly suitable for use in meat product processing.

Combination of meats: Considering the high prices of goat or sheep meat, many a time the price their emulsion based products goes very high. To tackle this these meats can be combined with poultry or other low cost meats and products with very good acceptability can be prepared.

13. Conclusion

Developing a variety of emulsion-based meat products is a highly effective strategy for popularizing and marketing processed meats in India. Emulsion-based products offer a key opportunity to develop a broad range of processed meat items, catering to a diverse array of consumer preferences. Emulsion-based meat products ensures the efficient use of lower quality meat, tough meat, trimmings and byproducts from various spent animals, including spent hens. The quality of the emulsion significantly impacts both product yield and palatability. A diverse range of appealing products, such as sausages, patties, nuggets, meatballs etc. can be made from the same emulsion. Further, addition of seasonal vegetables in these products could facilitate vegetables

consumption and provide balanced, healthy meat products, which may find wide popularity among Indian consumers. Addition of edible byproducts in emulsion could add variety, nutrition while making such products more economical. Therefore, exploration of market demand and popularization of these products especially in small cities could open new avenues in processed meat sector.

****References can be requested from the authors****

Chapter-19

Boifortification and fortification of milk and milk products

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1. Introduction

Globally, more than 2 billion individuals, or one in three people, are afflicted by micronutrient malnutrition, according to statistics by the Food and Agriculture Organization of the United Nations, with the World Health Organization further highlighting that 45% of child deaths globally are attributed to under-nutrition.

Nutritional deficiencies, a serious global health problem, are widespread in developing countries owing to escalating population, unavailability of resources and indeed
lack of legislation and governmental control. Due to inadequate intakes of vitamins and minerals, half of the world's population suffers from micronutrient malnutrition. An adequate amount of wholesome as well as diverse foods are required for the proper growth and development. In addition to calories requirements, these foods should provide various nutrients. Thus, various effective strategies for increasing the intakes of micronutrients by people in developing countries, especially the poor must be developed. Micronutrient malnutrition is devastating but preventable and it has been proved by a number of interventions. Fortification is a process of enhancing the nutritional content of foodstuff by adding one or more essential micronutrients that are deficit in the food.

Food fortification is a powerful method of providing a deficient nutrient to populations, provided the vehicle used for fortification is consumed by the poorest of the poor. Biofortification is a method of enhancing the density of vitamins and minerals in primary food through genetic engineering, typical breeding or chemical applications. Bio-fortification of staple food may be an efficient and cost-effective option to combat malnutrition particularly in poor populations that lack most of the essential micronutrients required in their daily diet.

Dairy products, especially milk, have been identified as one of the most fortified food items globally, despite it being considered a super food as is rich in calcium, vitamins, potassium, zinc, phosphorous and magnesium. Milk fortification helps in recovering the micronutrients that are lost during processing and the fact that milk is consumed by all population groups, it makes it a suitable medium to address under-nutrition. Also, milk is a good carrier for fortificants, as most are water soluble and is a natural carrier of fat-soluble vitamins, like vitamins A and D. Global evidence, according to the Food Safety and Standards Authority of India (FSSAI), indicate that

mandatory milk fortification legislation was first introduced in 1935. Currently, there are fourteen countries that have mandated milk fortification. Eleven of the fourteen countries fortify milk with both Vitamin A and D. India, the world's largest milk producer, issued a draft of regulations for mandatory fortification of packaged milk through the FSSAI in January 2021. The apex food regulator has been considering making fortification of milk mandatory for some time, in a bid to address the pertinent issue of Vitamin A and D deficiency in the country, which causes night blindness and bone disorders such as rickets and osteoporosis, respectively.

The Comprehensive National Nutrition Survey data 2019, suggested a high prevalence of lack of these two vitamins A and D in the population in India, thus becoming a growing public health concern. As per the survey, the prevalence of vitamin A deficiency stood at 18% for pre-school children, 22% school-age children and 16% adolescents. Vitamin D deficiency affected 14% of pre-school children, 18% of school-age children and 24% of adolescents in India. Recognizing the positive impact of food fortification in enhancing the well-being of its people, FSSAI recently issued provisions for licensing and registration of fortified food products in its Food Safety and Compliance System. The provisions cover processed food products categories, including milk alongside edible oil, juices, rice, wheat flour and maida (refined flour), cereal products, baked goods and salt.

As per FSSAI-issued standard operating procedures, food business operators (FBOs) are required to upload test reports showing levels of fortificants in the fortified food product. Results must be obtained from the FSSAI notified National Accreditation Board for Testing and Calibration Laboratories. With the proof, each product will be labelled with the +F endorsement mark, validating its claim for fortification. As per the FSSAI standards, milk needs to be fortified with Vitamin A and D at a level of 270 μg RE - 450 μg RE per litre and 5 μg -7.5 μg per litre, respectively.

A recent research studied the effects of fortified milk on morbidity in young children in North India. The results showed that regular intake of fortified milk resulted in 18 percent lower incidence of diarrhoea, 26 percent lower incidence of pneumonia, 7 percent fewer days with high fever and 15 percent fewer days sick with severe illness.

In India, a country in developmental transition, facing the dual burden of under-nutrition and infectious diseases as well as lifestyle-related degenerative conditions, the addition of milk to the list of mandatory fortified foods, is a step towards building a healthy population.

2. The difference between fortification and biofortification

Fortification and biofortification are food enrichment technologies that differ in their

approach; where in the former, fortificants are added directly to the food and processed, but the latter involves fortification at the production level of the food

production. Biofortification is a process of fortifying foods of animal/plant origin naturally during their growth and before the processing.

Various approaches available for biofortification of animal/crops products are:

- through agronomic practices,
- through breeding, and
- through biotechnology.

Biofortification is defined as the cost effective process to improve the concentration and bioavailability of the nutrients in foods through genetic engineering or conventional breeding techniques. Thus bringing agricultural and nutrition science together for reducing malnutrition—by increasing levels of nutrients like iron, pro-vitamin A, and zinc in staple foods at no additional cost to consumers.

3. Need for biofortification

Globally, deficiency of micronutrient affects two billion individuals and is predominantly widespread in rural populations of developing nations who rely on static diets that are generally found deficient in iron, zinc, and vitamin A. These deficiencies contribute considerably to the world disease problem and reduce productivity by limiting intellectual growth, weakening physical development, vision issues, and higher susceptibility to infectious diseases. Micronutrient intake in human diet can be improved by several strategies working together like diversification in diets, supplementation with minerals and food fortification, etc. These approaches need continual improvement in their applications as the existing levels of mineral fortification in food are quiet inadequate. But these problems can be addressed by biofortification, which improves the micronutrients in the animal/crops themselves by increasing their mineral levels and its bioavailability in the eatable parts. Therefore, biofortification could be a justifiable and price effective technique for densifying nutritional status of staple foods.

Biofortification of Food of Animal Origin

Foods of animal origin may also be subject to enrichment. In response to the high demand for vitamins A and D, there are commercially available animal products containing these vitamins, such as milk and dairy products, as well as eggs. A similar situation applies to the enrichment of animal products with polyunsaturated fatty acids, with the most common method being the addition of vegetable oils (rich in DHA) to processed meat products or their use as feedstock. Regarding the practical elements of

animal raw material enrichment, it should be mentioned that the use of raw feed materials
is common. In addition, aimed at the reduction of vitamin D deficiency, an attempt has been made through development of "Sunshine Eggs". The most common interventions with this purpose are in table eggs. These involve the addition of chelated forms of micronutrients to feed or organic and inorganic compounds. Recently, there has also been growing interest in the use of nanoparticles, mainly zinc, as an effective method of increasing the content of an element in table eggs. Particularly noteworthy, however, are methods based on "dual" biofortification, which use previously enriched plant materials as a source of micronutrients. An excellent example in this regard is the use of microalgae enriched with elements deficient in the diets of layinghens. Higher levels of bioaccumulation of copper and manganese compared to the dietary control has been reported. A similar result was reported when using biofortified soybean seeds at the germination stage. Thus, it seems promising to use not only plant but also raw animal materials as a solution to the problem of nutrient deficiencies in the human diet.

4. Guidelines for biofortification

Without any formal guidelines on production and consumption of Biofortified foods,
several considerations are reported by Codex alimenterius commission (Anonymous, 2014), some of them being:

Bioavailabilty of nutrients: The commission briefly defined bioavailability as the amount of an ingested nutrient that is absorbed and available for physiological functions that in turn is dependent on digestion, release from the food matrix, intestinal absorption, and transport to body cells. The nutrients are available to body, sometimes directly by consumption and sometimes by use of different processing/cooking methods. Traditional methods of cooking have been proven best in improving bioavailability of nutrients such as iron and carotenoids from staple food crops. Therefore, it is being stressed to back the biofortified foods with scientific evidences to help the population with bioavailability of nutrients.

Consumer perception: Commercialization of biofortified foods was resisted by masses due to change in aroma and color of some food products. Thus, with the introduction of biofortified product, it becomes necessary to aware the targeted population about its quality and benefits.

Safety: Because small amount of micronutrients are involved, so safety concerns are generally ignored. For example, toxicity questions have been raised in relation to vitamin A, regardless of the fact that only its precursors are involved. The concern arises that once in the body their conversion to vitamin A is controlled by a physiological self-regulating mechanism that prevents excess formation and storage of vitamin A. Thus, the consumption of this kind of products requires safety measures.

5. Biofortification as a Tool and Not a Remedy for the Problem of Hidden Hunger

Despite numerous studies indicating the high potential of biofortification in reducing microelement deficiencies in the human diet, it should be understood that it is a tool and not a remedy. First of all, it should be accepted that, like supplementation in the form of commercially available supplements, biofortified products cannot offer a substitute for a balanced diet. Lack of a varied diet can contribute to micronutrient deficiencies, including in groups that are particularly vulnerable to these deficiencies like pregnant women. A more varied diet should, therefore, be adopted as the primary solution to hidden hunger in the context of micronutrients. Although the important role of nutrient deficiencies in hidden hunger has led to an increased scope for food biofortification. Moreover, in the context of micronutrients themselves, it should be noted that "every coin has two sides". Over-supply of these nutrients may significantly contribute to negative health effects. The negative effects of an excessive supply of micronutrients can include a number of disease entities like neurodegenerative changes, diabetes, and endocrine and reproductive system disorders. It is, therefore, necessary to maintain appropriate levels of these nutrients, without exceeding the standards for the recommended intake. In the case of biofortified foods, the amount of direct research to date on bioavailability is small, and the issue should be considered more closely.

This is all the more important because, as already indicated, the amount of data on the bioavailability of micronutrients from biofortified products is insufficient. At the same time, it should be remembered that some of the micronutrients show competition in terms of absorption, as is the case with iron and manganese, iron and zinc, or many others. With this in mind, it should be assumed that in order to fully address the problem of hidden hunger, a balance must be maintained between the introduction of biofortified products, a balanced diet, and factors that limit the absorption of deficient micronutrients.

6. Biofortification of milk and cheese with microelements by dietary feed bio-preparations

Biofortification of milk and cheese with microelements by dietary manipulation of diet of goat have been attempted. The diet of goats was supplemented with soya-based preparations with Cu(II), Fe(II), Zn(II) and Mn(II), produced by biosorption, instead of mineral salts. The effect of milk and cheese biofortification in microelements was confirmed. In milk, the level of the following microelements was higher than in the control: Cu(II) – 8.2 %, Mn(II) – 29.2 %, Zn(II) – 14.6%. In cheese the content of Zn(II) obtained in enzymatic (19.8 %) and in acidic (120 %) coagulation was higher when compared to the control group. By using bio-preparations with microelements it was possible to produce new generation of functional food biofortified with microelements, by agronomic, and thus sustainable

and ethically acceptable way. Biofortified milk and cheese can be used as designer milk to prevent from micronutrient deficiencies

7. Folate bio-fortification of yoghurt and fermented milk

Folate, an essential vitamin, plays an important role in human life for the synthesis of nucleotides, vitamins and some amino acid. This vitamin cannot be synthesized by humans and must be obtained exogenously to prevent folate deficiency, neural tube defects (NTDs) and other related diseases. Folic acid, the chemically synthesized form of folate, is used for fortification and supplementation, but it can cause adverse effects such as vitamin B12 deficiency in high intake. Therefore, novel methods to increase concentrations of naturally occurring folate in foods have grabbed the interest of researchers. The application of bacterial cultures in food fermentation is a novel strategy to increase "natural" folate levels. Dairy products, especially yoghurt, are an appropriate choice for bio-fortification of folate as they contain folate-binding protein which improves folate bioavailability. This study will review the folate production by probiotic bacteria in fermented milk based on various strains and culture conditions.

8. Fortification

Food fortification is an economical, flexible, and socially acceptable technique to improve nutrition in a number of developed countries, for example, fortification of milk, margarine, and cereals has greatly reduced the occurrence of deficiencies. Among the foods that constitute the staple diet; flours, bread, and rice are being fortified with vitamin B complex, iron; hydrogenated oil and milk with fat soluble vitamins A and D; sugar with vitamin A and salt with iodine and iron, etc. Fortification first started in 1921, by adding iodine to salt and later in 1930s, with the addition of vitamin D to the milk for preventing rickets. In 1940s, fortification of flour and cereal products with iron, riboflavin, niacin, and thiamin was implemented and in 1990s, folic acid was added in the list for these fortified products.

9. Strategies for food fortification

Effective strategies need to be developed to increase the micronutrients' intake by the people in developing countries, more specifically by the poor. The fortification strategy must be cost effective and sustainable. The first strategy could be the food diversification that is, increasing the diversity in the food consumed. Ideally nutritionally balanced diet, which is made up of diverse food, must be accessible to every individual. But many millions of people cannot afford such diet hence this cannot be the practical solution. Supplementation or distribution of dietary supplements through various programs has been adopted as an alternative strategy. When suitable programs to deliver the supplements are available, this strategy has been proven very effective for short terms. The strategy of fortification of staple foods with vitamins and minerals is gaining impetus in many developing countries. Food

fortification has proven a successful strategy in many developed countries because it offers many advantages over food supplementation.
Food fortification can be done at three levels:

- Home fortification
- Industrial fortification
- Biofortification

10. Impact of fortification

In the industrialized countries, fortification of the common foods with micronutrients is one of the most economical and sustainable approaches for providing key micronutrients to a large population. Food fortification has now become a realistic option for developing countries as well due to the rapid advancements in modern food processing and packaging technologies. The documentation of impacts of various food fortification programs in Asia, Latin America and Africa have also shown that food fortification strategies are really compelling. It can be done for the following purposes: as a part of public health programs or policies in order to reduce the number of people having nutrient deficiencies in a population or purely for commercial purpose to supplement the foods with extra nutrients. Several technological considerations are important in case of analyzing the impact of food fortification which includes:

- Overall standard of the product
- Bioavailability of fortifying agent
- Stability of product Safety concern

These factors are important and interrelated to each other. For example, it is essential to ensure the bioavailability of the fortifying agent without affecting the overall quality of the product. Although bioavailability may be enhanced but the quality of product mainly its stability is at risk. One such example is in case of iron fortification, iron may react with fatty acids present in the food thus forming free radicals that further causes oxidation. Colour, taste, odor, and appearance are some other affected characteristics that eventually affect the product's acceptability to consumer. This phenomenon is associated with the solubility of the fortifying agent, typical in mineral salts. In general, the solubility of compound is increased to make the nutrient more bioavailable but it becomes more reactive with the fortified food at the same time, which makes it more susceptible to the changes in the product quality and less stable. Based upon the solubility of the iron salts, they could be divided into different categories in food fortification. First, are the water-soluble compounds having highest bioavailability, but they can easily modify the quality of most fortified foods.
Compounds that are soluble in diluted acids but slightly soluble in water are in second category. These compounds have quite good bioavailability but limited success has been achieved with fortification of foods with these compounds except in case of infant cereals. Iron salts that are slightly soluble in diluted acids but insoluble in water form third category, these have less reactivity with the components of food and are

relatively inert but their bioavailability is less. However, technological interventions have resulted in several reduced compounds of elemental iron having increased bioavailability, and less reactivity to the food at the same time thus causing no significant changes in quality of food. The nutrients isolated from foods are generally used for food fortifications by adding them back to processed foods that may be a limiting factor. Many of the nutrients from processed foods have been removed during the processing and thus the bioavailability of added nutrients may not be the same as that of whole, original food. This can be understood by the example of skim milk from which fat is removed, and then fortified with vitamin A and vitamin D. Both Vitamins A and D are not soluble in water and are fat soluble, so skim milk lacking the fats may not be able to provide a person enough quantities of these vitamins as provided by whole milk. Besides bioavailability, nutrient absorption is also an important technological consideration. Nutrient absorption is affected by many phytochemicals such as polyphenols. Mixture containing several vitamins and minerals can be added to dry and relatively inert foods, such as cereals. But very little information is available about the interactions among nutrients and their quantitative impact on the absorption of individual nutrients when they are added as a mixture. Thus estimation of quantities of each nutrient that can be added to a particular food becomes difficult. For example, large amounts of calcium in a fortified food can inhibit the iron absorption whereas, vitamin C has a stimulating and opposite impact that increases the absorption of iron. Another important consideration is the stability of the fortificant. Stability of nutrients may depend upon a number of factors such as temperature, pH, air, light and oxygen. These parameters need to be controlled during processing and storage of fortified foods. For example, vitamin C is extremely volatile under high heat and humidity conditions. Significant concentrations of vitamins especially vitamins A, C, folic acid, and niacin are lost during different stages of processing and/or storage. Therefore, whole purpose of fortification is defeated if nutrients are lost after fortification because nutrients are not present at the time of consumption.

Advantages of fortification

As far as public health is concerned, fortification of food is one of the most cost-effective intervention and the technologies for adding different nutrients to foods is well established. As compared to other interventions, food fortification also offers a number of other advantages like:

- Change in eating habits and dietary patterns of a population are not essential.
- Individual compliance is not required.
- A substantial proportion of the recommended dietary allowances (RDA) for different micronutrients can be delivered simultaneously in a continuous manner.

Food fortifications can easily be merged with the prevailing food production and distribution system, and therefore, are sustainable for a long period of time, however to derive maximum benefits from food fortification with respect to combating malnutrition the fortification strategy need to be adopted.

Limitations/ disadvantages of fortification

Though it is generally accepted that food fortification can have a huge positive impact on public health, but there are certain limitations of this strategy:

- Fortified foods are not a replacement for a good quality diet that supplies adequate amounts of energy, protein, essential fats and other food constituents required for optimal health inspite of containing increased amount of selected micronutrients.
- A specific fortified foodstuff might not be suitable for all members of a target population. Irrespective whether or not a person get benefited from fortification, all the persons of a population is exposed to increased levels of micronutrients in food on the contrary.
- Fortified complementary foods may be more suitable for infants and young children who consume relatively small amounts of food, because they would not be able to obtain their recommended dietary allowances of all micronutrients by consuming universally fortified staple of condiments.
- Due to low purchasing power, fortified foods often fail to reach the poorest segments of the general population who have restricted access to fortified foods and are at the greatest risk of micronutrient deficiency.
- Due to inadequate consumption of the traditional diet, multiple micronutrient deficiencies co-exist among very low-income population groups. Despite of availability of multiple micronutrient fortification technologies, it is unrealistic that the poor will be able to obtain recommended intakes of all micronutrients from fortified foods alone.
- Technological issues of food fortification especially the appropriate levels of nutrients, stability of fortificants, nutrient interactions, physical properties, as well as acceptability by consumers including cooking properties and taste have yet to be fully determined.
- The amount of a particular fortificant that can be successfully added may be limited by the nature of the fortificant, and/or the food vehicle. For example, color and flavor of many foods are significantly changed due to addition of some iron fortificants. Some iron fortificants can lead to the destruction of vitamin A and iodine fortificants. Some strategies like microencapsulation of fortificants with protective coatings has been developed for solving these problems, but some difficulties still persist.
- Organoleptic properties of the food or the stability of the nutrients can be adversely affected due to interactions between fortificant nutrients.
- Though food fortification is more economical in comparison to other interventions, yet significant costs are involved with the fortification process of food that may be a limiting factor in effective implementation of food fortification programs.
- Limited absorption and bioavailability are the major problems associated with food fortification.

- In most of the cases, fortification is generally done by utilizing synthetic salts. The high concentration of some forms of the fortificants may be toxic, whereas some other forms may be safe at the same or even higher concentrations. For example, higher concentration of betacarotene is safe for Vitamin A fortification whereas much lower dose of Retinol, the active form of Vitamin A, is toxic. A synthetic form of Vitamin K, Menadione is also known to be toxic.

Nutrient for fortification of milk and milk products

Iron fortification

Iron fortification of milk or dairy products induces several bio physicochemical modifications with important consequences.Iron fortification of food is regarded as the most cost-effective method for reducing the prevalence of nutritional iron deficiency. Nutritional anemia remains very prevalent in developing countries, and iron fortification appears until recently to have had little impact.

Iodine fortification

Iodine concentration of organic summer milk was significantly lower than the iodine concentration of organic winter milk. No significant relation between iodine content and milk fat percentage with regard to geographical sampling location. Whey cheese iodine concentration was significantly higher than iodine concentration in casein cheeses. Goiter can be regulated by use of iodine fortified dairy products.

Vitamin fortification

Natural and added forms of vitamin A (all- trans-retinol, retinyl esters and beta-carotene) and vitamin E (alpha-tocopherol, alpha tocopheryl acetate) were determined in commercially available dairy products that are frequently consumed. Retinyl esters, beta carotene and alpha-tocopherol are in natural dairy products, whereas retinyl and alpha-tocopheryl acetate occur in most vitamin-fortified products. Since Vitamin D is a fat-soluble vitamin, it cannot be added to a wide variety of foods. Foods that it is commonly added to margarine, vegetable oils and dairy products. Rickets could be cured by these foods. Their results showed that sunlight exposure and cod liver oil were the cure. It was not until the 1930s that vitamin D was actually linked to curing rickets. This discovery led to the fortification of common foods such as milk, margarine, and breakfast cereals. The astonishing statistics of approximately 80–90% of children showing varying degrees of bone deformations due to vitamin D deficiency to being a very rare condition. The current RDA for infants aged 0–6 months is 10 μg (400 International Units (IU))/day and for adults over 19 years of age it is 15 μg (600 IU)/day.

Fish oil fortification

Fortification of dairy products with long-chain polyunsaturated fatty acid, however, the level of fortification was limited. The highest level of fortification was obtained for solid, high-fat dairy products (spreadable fresh cheese, butter and processed cheeses), especially when flavorings were present.

Probiotic fortification

Lactobacillus acidophilus or *bifdus* does not grow and survive in yogurt for a long period of time. A differential inoculation procedure has been developed where by *Lactobacillus acidophilus* is first inoculated into heat treated. Later, the regular yogurt cultures *Streptococcus thermophiles* and *Lactobacillus bulgaricus* are inoculated into the acidophilus growing yogurt mix. Dietetic fiber was introduced into the fruit base and then mixed with yogurt. Dietetic fiber enhances the population of *L. acidophilus*.

Casienate fortification

Yoghurt fortification with caseinates, co-precipitate and blended dairy powders in low-fat yoghurt. These dairy products were characterised for pH, moisture, lactose, mineral and protein fractions. Yoghurts enriched with caseinates had higher viscosity and syneresis index than yoghurts based on concentrated skimmed milk fortified with co-precipitate or blended dairy products. One blended dairy product was tested to manufacture low-fat yoghurt on an industrial scale, yielding good rheological properties and lower cost than traditional enrichment with skimmed milk powder.

Fiber fortification

Insoluble dietary fiber from five different sources (soy, rice, oat, corn and sugar beet) were used to fortify sweetened plain yogurt. In general, fiber addition led to lower overall flavour and texture scores. A grainy flavor and a gritty texture were intense in all fiber-fortified yogurts, except in those made with oat fiber. The evolution of organic acids during the fermentation and cold storage of control and oat-fiber-fortified yogurts showed a similar pattern; only acetic and propionic acids were found in significantly higher amounts in the fiber- fortified product.

****References can be requested from the authors****

Chapter-20

Biofortification of milk and milk products

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Globally, more than 2 billion individuals, or one in three people are affected by micronutrient malnutrition, according to statistics by the Food and Agriculture Organization of the United Nations, further, the World Health Organization highlighting that 45% of child deaths globally are attributed to under-nutrition.

Nutritional deficiencies, a serious global health problem, are widespread in developing countries owing to escalating population, unavailability of resources and indeed lack of legislation and governmental control. Due to inadequate intakes of vitamins and minerals, half of the world's population suffers from micronutrient malnutrition. An adequate amount of wholesome as well as diverse foods are required for the proper growth and development. In addition to calories requirements, these foods should provide various nutrients. Thus, various effective strategies for increasing the intakes of micronutrients by people in developing countries, especially the poor must be developed. Micronutrient malnutrition is devastating but preventable and it has been proved by a number of interventions. Fortification is a process of enhancing the nutritional content of foodstuff by adding one or more essential micronutrients that are deficit in the food.

Food fortification is a powerful method of providing a deficient nutrient to populations, provided the vehicle used for fortification is consumed by the poorest of the poor. Biofortification is a method of enhancing the density of vitamins and minerals in primary food through genetic engineering, typical breeding or chemical applications. Bio-fortification of staple food may be an efficient and cost-effective option to combat malnutrition particularly in poor populations that lack most of the essential micronutrients required in their daily diet.

Dairy products, especially milk, have been identified as one of the most fortified food items globally, despite it being considered a super food as is rich in calcium, vitamins, potassium, zinc, phosphorous and magnesium. Milk fortification helps in recovering the micronutrients that are lost during processing and the fact that milk is consumed by all population groups, it makes it a suitable medium to address under-nutrition. Also, milk is a good carrier for fortificants, as most are water soluble and is a natural carrier of fat-soluble vitamins, like vitamins A and D. Global evidence, according to the Food Safety and Standards Authority of India (FSSAI), indicate that

mandatory milk fortification legislation was first introduced in 1935. Currently, there are fourteen countries that have mandated milk fortification. Eleven of the fourteen countries fortify milk with both Vitamin A and D. India, the world's largest milk producer, issued a draft of regulations for mandatory fortification of packaged milk through the FSSAI in January 2021. The apex food regulator has been considering making fortification of milk mandatory for some time, in a bid to address the pertinent issue of Vitamin A and D deficiency in the country, which causes night blindness and bone disorders such as rickets and osteoporosis, respectively.

The Comprehensive National Nutrition Survey data 2019, suggested a high prevalence of lack of these two vitamins A and D in the population in India, thus becoming a growing public health concern. As per the survey, the prevalence of vitamin A deficiency stood at 18% for pre-school children, 22% school-age children and 16% adolescents. Vitamin D deficiency affected 14% of pre-school children, 18% of school-age children and 24% of adolescents in India. Recognizing the positive impact of food fortification in enhancing the well-being of its people, FSSAI recently issued provisions for licensing and registration of fortified food products in its Food Safety and Compliance System. The provisions cover processed food products categories, including milk alongside edible oil, juices, rice, wheat flour and maida (refined flour), cereal products, baked goods and salt.

As per FSSAI-issued standard operating procedures, food business operators (FBOs) are required to upload test reports showing levels of fortificants in the fortified food product. Results must be obtained from the FSSAI notified National Accreditation Board for Testing and Calibration Laboratories. With the proof, each product will be labelled with the +F endorsement mark, validating its claim for fortification. As per the FSSAI standards, milk needs to be fortified with Vitamin A and D at a level of 270 μg RE - 450 μg RE per litre and 5 μg -7.5 μg per litre, respectively.

A recent research studied the effects of fortified milk on morbidity in young children in North India. The results showed that regular intake of fortified milk resulted in 18 percent lower incidence of diarrhoea, 26 percent lower incidence of pneumonia, 7 percent fewer days with high fever and 15 percent fewer days sick with severe illness.

In India, a country in developmental transition, facing the dual burden of under-nutrition and infectious diseases as well as lifestyle-related degenerative conditions, the addition of milk to the list of mandatory fortified foods, is a step towards building a healthy population.

The difference between fortification and biofortification

Fortification and biofortification are food enrichment technologies that differ in their approach; where in the former, fortificants are added directly to the food and processed, but the latter involves fortification at the production level of the food production. Biofortification is a process of fortifying foods of animal/plant origin naturally during their growth and before the processing.

Biofortification is defined as the cost effective process to improve the concentration and bioavailability of the nutrients in foods through genetic engineering or conventional breeding techniques. Thus bringing agricultural and nutrition science together for reducing malnutrition—by increasing levels of nutrients like iron, pro-vitamin A, and zinc in staple foods at no additional cost to consumers.

Various approaches available for biofortification of animal/crops products are:

- through agronomic practices
- through breeding
- through biotechnology

Need for biofortification

Globally, deficiency of micronutrient affects two billion individuals and is predominantly widespread in rural populations of developing nations who rely on static diets that are generally found deficient in iron, zinc, and vitamin A. These deficiencies contribute considerably to the world disease problem and reduce productivity by limiting intellectual growth, weakening physical development, vision issues, and higher susceptibility to infectious diseases. Micronutrient intake in human diet can be improved by several strategies working together like diversification in diets, supplementation with minerals and food fortification, etc. These approaches need continual improvement in their applications as the existing levels of mineral fortification in food are quiet inadequate. But these problems can be addressed by biofortification, which improves the micronutrients in the animal/crops themselves by increasing their mineral levels and its bioavailability in the eatable parts. Therefore, biofortification could be a justifiable and price effective technique for densifying nutritional status of staple foods.

Guidelines for biofortification

Without any formal guidelines on production and consumption of biofortified foods, several considerations are reported by Codex alimenterius commission, some of them are:

Bioavailabilty of nutrients: The commission briefly defined bioavailability as the amount of an ingested nutrient that is absorbed and available for physiological functions that in turn is dependent on digestion, release from the food matrix, intestinal absorption, and transport to body cells. The nutrients are available to body, sometimes directly by consumption and sometimes by use of different processing/cooking methods. Traditional methods of cooking have been proven best in improving bioavailability of nutrients such as iron and carotenoids from staple food crops. Therefore, it is being stressed to back the biofortified foods with scientific evidences to help the population with bioavailability of nutrients.

Consumer perception: Commercialization of biofortified foods was resisted by masses due to change in aroma and color of some food products. Thus, with the introduction of biofortified product, it becomes necessary to aware the targeted population about its quality and benefits.

Safety: Because small amount of micronutrients are involved, so safety concerns are generally ignored. For example, toxicity questions have been raised in relation to

vitamin A, regardless of the fact that only its precursors are involved. The concern arises that once in the body their conversion to vitamin A is controlled by a physiological self-regulating mechanism that prevents excess formation and storage of vitamin A. Thus, the consumption of this kind of products requires safety measures.

Biofortification of Food of Animal Origin

Foods of animal origin may also be subject to enrichment. In response to the high demand for vitamins A and D, there are commercially available animal products containing these vitamins, such as milk and dairy products, as well as eggs. A similar situation applies to the enrichment of animal products with polyunsaturated fatty acids, with the most common method being the addition of vegetable oils (rich in DHA) to processed meat products or their use as feedstock. Regarding the practical elements of animal raw material enrichment, it should be mentioned that the use of raw feed materials is common. In addition, aimed at the reduction of vitamin D deficiency, an attempt has been made through development of "Sunshine Eggs". The most common interventions with this purpose are in table eggs. These involve the addition of chelated forms of micronutrients to feed or organic and inorganic compounds. Recently, there has also been growing interest in the use of nanoparticles, mainly zinc, as an effective method of increasing the content of an element in table eggs. Particularly noteworthy, however, are methods based on "dual" biofortification, which use previously enriched plant materials as a source of micronutrients. An excellent example in this regard is the use of microalgae enriched with elements deficient in the diets of laying hens. Higher levels of bioaccumulation of copper and manganese compared to the dietary control has been reported. A similar result was reported when using biofortified soybean seeds at the germination stage. Thus, it seems promising to use not only plant but also raw animal materials as a solution to the problem of nutrient deficiencies in the human diet.

Biofortification of milk and cheese with microelements by dietary feed bio-preparations

Biofortification of milk and cheese with microelements by dietary manipulation of diet of goat have been attempted. The diet of goats was supplemented with soya-based preparations with Cu(II), Fe(II), Zn(II) and Mn(II), produced by biosorption, instead of mineral salts. The effect of milk and cheese biofortification in microelements was confirmed. In milk, the level of the following microelements was higher than in the control: Cu(II) – 8.2 %, Mn(II) – 29.2 %, Zn(II) – 14.6%. In cheese the content of Zn(II) obtained in enzymatic (19.8 %) and in acidic (120 %) coagulation was higher when compared to the control group. By using bio-preparations with microelements it was possible to produce new generation of functional food biofortified with microelements, by agronomic, and thus sustainable and ethically acceptable way. Biofortified milk and cheese can be used as designer milk to prevent from micronutrient deficiencies

Folate bio-fortification of yoghurt and fermented milk

Folate, an essential vitamin, plays an important role in human life for the synthesis of nucleotides, vitamins and some amino acid. This vitamin cannot be

synthesized by humans and must be obtained exogenously to prevent folate deficiency, neural tube defects (NTDs) and other related diseases. Folic acid, the chemically synthesized form of folate, is used for fortification and supplementation, but it can cause adverse effects such as vitamin B12 deficiency in high intake. Therefore, novel methods to increase concentrations of naturally occurring folate in foods have grabbed the interest of researchers. The application of bacterial cultures in food fermentation is a novel strategy to increase "natural" folate levels. Dairy products, especially yoghurt, are an appropriate choice for bio-fortification of folate as they contain folate-binding protein which improves folate bioavailability. This study will review the folate production by probiotic bacteria in fermented milk based on various strains and culture conditions.

Biofortification as a Tool and Not a Remedy for the Problem of Hidden Hunger

Despite numerous studies indicating the high potential of biofortification in reducing microelement deficiencies in the human diet, it should be understood that it is a tool and not a remedy. First of all, it should be accepted that, like supplementation in the form of commercially available supplements, biofortified products cannot offer a substitute for a balanced diet. Lack of a varied diet can contribute to micronutrient deficiencies, including in groups that are particularly vulnerable to these deficiencies like pregnant women. A more varied diet should, therefore, be adopted as the primary solution to hidden hunger in the context of micronutrients. Although the important role of nutrient deficiencies in hidden hunger has led to an increased scope for food biofortification. Moreover, in the context of micronutrients themselves, it should be noted that "every coin has two sides". Over-supply of these nutrients may significantly contribute to negative health effects. The negative effects of an excessive supply of micronutrients can include a number of disease entities like neurodegenerative changes, diabetes, and endocrine and reproductive system disorders. It is, therefore, necessary to maintain appropriate levels of these nutrients, without exceeding the standards for the recommended intake. In the case of biofortified foods, the amount of direct research to date on bioavailability is small, and the issue should be considered more closely.

This is all the more important because, as already indicated, the amount of data on the bioavailability of micronutrients from biofortified products is insufficient. At the same time, it should be remembered that some of the micronutrients show competition in terms of absorption, as is the case with iron and manganese, iron and zinc, or many others. With this in mind, it should be assumed that in order to fully address the problem of hidden hunger, a balance must be maintained between the introduction of biofortified products, a balanced diet, and factors that limit the absorption of deficient micronutrients.

****References can be requested from the authors****

Chapter-21

Microbiological Quality Standards and Methods for Microbiological Analysis of Animal Origin Foods

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1. Introduction

Foods of animal origin are excellent source of high-quality protein, vitamins and minerals therefore are not only nutritious to consumers, but are also excellent source of nutrients for microbial growth. Foodborne diseases result from the ingestion of contaminated foods and food products and include a broad group of illnesses caused by either bacteria and bacterial toxins, viruses, zoonotic parasites, fungi and fungal toxins, pesticide residues, heavy metals, drug residues, food adulterants or food additives etc. which contaminate food at different points in the food production and preparation process. Bacteria are the most common foodborne pathogens, accounting for more than 90% of the total outbreaks of foodborne illness in the world (Beran *et al.,* 1991; Potter *et al.,* 1997). Globally, increase in the incidence of foodborne illnesses continue to be reported, often associated with outbreaks due to food contamination that raise international concern.

Food safety has emerged as an important global issue as foodborne diseases present a widespread and growing public health concern. Foodborne zoonotic pathogens are influencing the safety of foods and can cause serious adverse effects to human and animal health. Consequently, microbiological quality control has become the priority in the food industry and it aims towards minimizing the risks connected to food pathogens. The rapid and precise monitoring and detection of foodborne pathogens is one of the most effective ways to control and prevent foodborne diseases. Traditional microbiological detection and identification methods for food pathogens are well known to be time consuming and laborious and increasingly being perceived as insufficient to meet the demands of rapid food testing. Advancements in biotechnology and bioinformatics have resulted in the development of novel testing technologies that enable more reliable and faster detection of food pathogens. These novel methods, although still not applied routinely in everyday practice, are the promising alternatives that can replace or act addendum to current reference methods, in near future.

Food safety practices have vastly improved now-a-days and consumers have become much more aware of food safety issues in the food processing environment. There are many methodical programs like good agricultural practices (Kay *et al.,* 2008; Umali-Deininger and Sur, 2007), good manufacturing practices (Mucchetti *et al.,* 2008; Umali-Deininger and Sur, 2007), hazard analysis and critical control point (HACCP) (Jin *et al.,* 2008; Taylor, 2007) and the food code (Piatek and Ramaen, 2001), indicating approaches which can significantly reduce the pathogenic microorganisms in food. But still, the role of pathogen detection technology is vital, which is the key to the prevention and identification of problems related to health and safety.

Food-borne diseases are mainly caused by pathogenic microorganisms which are transmitted to humans from infected food and water. There are more than 250 known diseases caused by different foodborne pathogenic microorganisms, including viruses, bacteria, fungi, mycoplasma, and parasites. Of these, bacteria are the most common pathogens, accounting for more than 70% of the total outbreaks of foodborne illness in the world. Detection of these pathogenic microorganisms in food is often difficult due to the high number of contaminating microorganisms and a low number of the pathogens of concern. Traditional methods of identification of food-borne pathogens are time consuming, laborious and technically demanding and therefore, there is a need for the development of innovative methods for their rapid identification. Current trends in the nutrition and food technology are demanding food microbiologists to ensure a safe food supply.

Food safety has emerged as an important global issue due to international trade and public health implications. Despite advances in hygiene, consumer knowledge, food treatment and processing, FBDs still represent a significant threat to public health, worldwide. The term FBDs covers illnesses acquired through consumption of contaminated food. In response to the increasing number of foodborne illnesses, governments all over the world are intensifying their efforts to improve food safety. Due to widespread poverty and malnutrition in developing countries, programs directed towards the promotion of adequate access to food that satisfy calorie needs and minimize hunger have precedence over programs designed to ensure wholesomeness and quality of food. In short, the emphasis so far has been more on food adequacy rather than on food quality. Therefore, the World Health Assembly adopted a resolution (WHA 53.15) in which, the World Health Organization (WHO) was asked "*to give greater emphasis on food safety.*

Growing international trade, migration and travel - increased the spread of dangerous pathogens and contaminants in food. Due to globalization of food marketing and distribution- both accidentally or deliberately contaminated food can affect health of people in many countries at the same time. In today's interconnected and interdependent world - local FBD outbreaks - a potential threat to entire globe. In 1991, cholera which was thought to have originated from contaminated seafood harvested off the coast of Peru, rapidly spread across Latin America resulting in approximately 400,000 reported cases and more than 4000 deaths in several countries. The identification of one single contaminated food ingredient can lead to the recall of

tonnes of food products leading to considerable economic losses in production and from trade embargoes, as well as damage to the tourist industry. In early 2008, an outbreak of avian influenza in Bangalore, led to an import ban of Indian poultry products in Middle East, resulting in losses totaling hundreds of thousands of USD to the Indian economy.

The term Food-borne diseases (also frequently referred to as food poisoning), covers illnesses acquired through consumption of contaminated food and includes foodborne intoxications and food- borne infections. Globally, the WHO has estimated that approximately 3-5 billion episodes of diarrhea and more than 1.8 million deaths occur in children under 5 years of age, and a significant proportion of these results from consumption of food mainly food of animal origin contaminated with microbial pathogens or toxins. According to the CDC, an estimated 76 million cases of food-borne disease are reported annually in the United States of America with approximately 5000 deaths. In USA, diseases caused by the major pathogens alone are estimated to cost up to US $35 billion annually (1997) while in UK nearly £1.5 billion (2010), in medical costs and lost productivity. Approximately $9.3 billion to $12.9 billion cost paid on human disease treatment caused by six major pathogens including Salmonella, Campylobacter jejuni, Escherichia coli O157:H7, Listeria monocytogenes, Staphylococcus aureus, and Clostridium perfringens (USDA, 2011) and all these are foodborne.

Developing countries bear the brunt of the problem due to the presence of a wide range of food-borne pathogens, favorable conditions due to un-hygienic practices. The burden of infectious diseases continues to be a major constraint in sustained agricultural development and food security. In India, an estimated 5,00,000 children below five years age die each year due to diarrhea (UNICEF estimate 1000/day). These figures jeopardize international and India's own development efforts including the achievement of the Millennium Development Goals (MDGs).

At present, the reporting and surveillance of food-borne diseases in developing countries is grossly neglected. Therefore, the exact extent of the problem of food-borne diseases in developing countries including India has not been fully understood. Most cases go unreported as scientific investigations are rarely feasible. Studies revealed that food-borne diseases are a serious health hazard and important cause of morbidity and mortality in developing countries. Although, most of the studies showed the incidence of food-borne diseases, they either lacked data on the organisms involved or the food implicated. The actual scenario of food-borne diseases can emerge only with proper emphasis on foodborne disease surveillance including identification of foodborne pathogens involved. The requirement is to establish a National Foodborne Disease Surveillance System.

Foodborne diseases (FBDs) are a substantial public health, economic and social burden causing high morbidity and mortality. Global burden of infectious diarrhoea is estimated to be 3-5 billion cases and 1.5 million deaths, mainly in young children. About 600 million people (1 in 10) affected by FBDs as per WHO, 2015 leading to 420000 deaths, and loss of 33 million DALYs, which is a gross underestimation. About

33 % of foodborne deaths occur in children under 5 years of age. Countries have realized the need to estimate National burden of FBDs but there is lack of political commitment, technical and financial resources and data to estimate burden of FBDs. These barriers have further enhanced as a result of Covid 19 pandemic. Foodborne pathogens are responsible for more than 2/3rd of FBDs (Yan et al., 2017). To measure the burden of infectious diseases, Integrated disease surveillance project (IDSP) network was launched in India in 2004. Analysis of IDSP data from 2011-15 shows that FBD outbreaks together with ADD constitute nearly half of all outbreaks. Most common FBPs include: Salmonella, E. coli, Clostridium perfringens, Listeria, Campylobacter, and Noroviruses. Others include Bacillus cereus, S. aureus, Cl. botulinum, Hepatitis A, Shigella and Vibrio spp.

2. Microbiological standards on livestock products:

Food Safety and Standards Act was notified in 2011 which elaborates the microbiological requirements of foods. The microbiological standards have been divided in to process hygiene and food safety criteria. The microbiological requirements of various meat and milk-based foods are summarized below:

2.1. Process Hygiene Criteria:

"Microbial Standards for Meat and Meat Products

Table 5A: Microbiological Standards for Meat and Meat Products- Process Hygiene Criteria

S. No.	Product Category[1]	Aerobic Plate Count				Yeast and Mold Count				*Escherichia coli*				*Staphylococcus aureus* (Coagulase +ve)			
		Sampling Plan		Limits (cfu/g)		Sampling Plan		Limits (cfu/g)		Sampling Plan		Limits (cfu/g)		Sampling Plan		Limits (cfu/g)	
		n	c	m	M	n	c	m	M	n	c	m	M	n	c	m	M
(1)	Fresh meat/ Chilled meat[2]	5	3	$1x10^6$	$5x10^6$	5	2	$1x10^4$	$5x10^4$	5	2	$1x10^2$	$1x10^3$	5	2	$1x10^2$	$1x10^3$
(2)	Frozen meat[2]	5	2	$1x10^5$	$5x10^6$	5	2	$1x10^3$	$1x10^4$	5	2	1x10	$1x10^2$	5	2	10	$1x10^2$
(3)	Raw marinated/minced/comminuted meat[2]	5	2	$5x10^5$	$5x10^6$	5	2	$1x10^2$	$1x10^3$	5	2	$1x10^2$	$1x10^3$	5	2	$1x10^2$	$1x10^3$
(4)	Semi-cooked /Smoked Meat/ meat food Product[1]	5	2	$1x10^4$	$1x10^5$	5	2	10	$1x10^2$	5	2	10	$1x10^2$	5	2	10	$1x10^2$
(5)	Cured/Pickled meat	5	2	$5x10^2$	$5x10^3$	5	2	$1x10^2$	$1x10^3$	5	2	10	$1x10^2$	5	1	$1x10^2$	$1x10^3$
(6)	Fermented meat products	NA	NA	NA	NA	NA	NA	NA	NA	5	2	10	$1x10^2$	5	1	$1x10^2$	$1x10^3$
(7)	Dried/dehydrated meat product	5	2	$1x10^3$	$1x10^4$	5	2	$1x10^2$	$1x10^3$	5	2	10	$1x10^2$	5	1	10	$1x10^2$
(8)	Cooked Meat Products	5	2	$1x10^3$	$1x10^4$	5	1	10	$1x10^2$	5	2	10	$1x10^2$	5	1	10	$1x10^2$
(9)	Canned/Retort pouch Meat Products	NA	NA	NA	NA	NA	NA	NA	NA	5	0	Absent	NA	5	0	Absent	NA
	Test Methods[3]	IS: 5402/ISO 4833				IS: 5403/ISO 21527				IS: 5887 Part1 or ISO 16649-2				IS 5887 : Part 2 or IS 5887 Part 8 (Sec 1)/ ISO : 6888-1 or IS 5887 Part 8 (Sec 2)/ISO 6888-2			

2. In the Food Safety and Standards (Food Products Standards and Food Additives) Regulations, 2011, in APPENDIX B relating to "Microbiological Requirements",-

(A) for TABLE 2 and the entries relating thereto, the following TABLE and the entries shall be substituted, namely:-

"Microbiological Standards for Milk and Milk Products

Table-2A Microbiological Standards for Milk and Milk Products–Process Hygiene Criteria

Sr. No.	Product Description[1]	Aerobic Plate Count				Coliform Count[4]				*Staphylococcus aureus* (Coagulase positive)				Yeast and Mold Count				*Escherichia coli*			
		Sampling Plan		Limit (cfu)		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)	
		n	c	m	M	n	c	m	M	n	c	m	M	n	c	m	M	n	c	m	M
1	Pasteurized boiled Milk/ Flavored Milk	5	3	$3x10^4$/ml	5x 10^4/ml	5	0	<10/ml	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	Pasteurized Cream	5	3	$5x10^4$/g	$7.5x10^4$/g	5	0	<10/g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	Sterilized milk /UHT milk / Evaporated Milk	NA																			
4	Sterilized / UHT Cream	NA																			
5	Sweetened Condensed Milk	5	3	$5x10^2$/g	$1x10^3$/g	5	0	<10/g	NA	5	0	<10/g	NA	5	0	<10/g	NA	NA	NA	NA	NA
6	Pasteurized Butter[2]	5	3	$2.5x10^4$/g	$5x10^4$/g	5	2	10/g	20/g	5	2	10/g	50/g	5	3	20/g	50/g	5	0	Absent/g	NA
7	Milk Powder ; SMP, Partly SMP ; Dairy Whitener ; Cream Powder ; Ice Cream Mix Powder ; Lactose ; Whey based Powder ; Butter Milk Powder ; Casein Powder [3]	5	2	$3x10^4$/g	$5x10^4$/g	5	2	10/g	50/g	5	2	10/g	$1x10^2$/g	5	0	50/g	NA	NA	NA	NA	NA
8	Infant Milk Food, Infant Formulae, Infant Milk Substitute[4]	5	2	$5x10^2$/g	$5x10^3$/g	NA	NA	NA	NA	5	0	<10/g	NA	5	0	<10/g	NA	NA	NA	NA	NA

Sr. No.	Product Description[1]	Aerobic Plate Count				Coliform Count[4]				*Staphylococcus aureus* (Coagulase positive)				Yeast and Mold Count				*Escherichia coli*			
		Sampling Plan		Limit (cfu)		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)	
		n	c	m	M	n	c	m	M	n	c	m	M	n	c	m	M	n	c	m	M
	Follow Up Formula / Cereal Based Complimentary food	5	2	$1x10^3$/g	$1x10^4$/g	10	0	<10/g	NA	5	0	<10/g	NA	5	0	<10/g	NA	10	0	Absent/g	NA
9	Ice Cream, Frozen Dessert, Milk Lolly, Ice Candy	5	3	$1x10^5$/g	$2x10^5$/g	5	3	10/g	$1x10^2$/g	5	2	10/g	$1x10^2$/g	NA	NA	NA	NA	5	0	Absent/g	NA
10	Processed Cheese/ Cheese Spread	5	2	$2.5x10^4$/g	$5x10^4$/g	5	0	<10/g	NA	5	0	<10/g	NA	NA	NA	NA	NA	NA	NA	NA	NA
11	All other cheeses categories including fresh cheeses / Cheddar / Cottage /Soft /Semi Soft [5]	NA	NA	NA	NA	5	3	$1x10^2$/g	$5x10^2$/g	5	3	10/g	$1x10^2$/g	5	3	$1x10^2$/g	$5x10^2$/g	5	0	<10 /g	NA
12	Fermented Milk Products	NA	NA	NA	NA	5	2	10/g	$1x10^2$/g	5	2	10/g	$1x10^2$/g	5	3	50/g	$1x10^2$/g	5	0	Absent/g	NA
13	Paneer/ Chhana/ chhana based sweets	5	3	$1.5x10^5$/g	$3.5x10^5$/g	5	3	10/g	$1x10^2$/g	5	3	10/g	$1x10^2$/g	5	3	50/g	$1.5x10^2$/g	5	0	<10/g	NA
14	Khoa/ Khoa based sweets	5	3	$2.5x10^4$/g	$7.5x10^4$/g	5	2	50/g	$1x10^2$/g	5	3	10/g	$1x10^2$/g	5	3	10/g	50/g	5	0	<10/g	NA
	Test Methods[7]	**IS 5402/ ISO: 4833**				**IS 5401 Part 1/ISO : 4832**				**IS 5887 : Part 2 or IS 5887 Part 8 (Sec 1)/ ISO : 6888-1 or IS 5887 Part 8 (Sec 2)/ ISO 6888-2**				**IS:5403 or ISO : 6611**				**IS 5887 : Part 1 or ISO : 16649-2**			

2.2. Food Safety criteria:

Table 5B: Microbiological Standards for Meat & Meat Products- Food Safety Criteria

Sr. No.	Product Category[1]	*Salmonella*			*Listeria monocytogenes*			Sulphite Reducing Clostridia				*Clostridium Botulinum*				*Campylobacter* Spp*			
		Sampling Plan		Limits (cfu/25g)	Sampling Plan		Limits (cfu/25g)	Sampling Plan		Limits (cfu/g)		Sampling Plan		Limits (cfu/g)		Sampling Plan		Limits (cfu/g)	
		n	c	m M	n	C	m M	n	c	m	M	n	c	m	M	n	c	m	M
1.	Fresh meat / Chilled meat[2]	5	0	Absent	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.	Frozen meat[2]	5	0	Absent	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.	Raw marinated/minced/comminuted meats[2]	5	0	Absent	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4.	Semi-cooked /Smoked Meat/meat food Product[2]	5	0	Absent	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5	0	Absent	
5.	Cured/Pickled meat	5	0	Absent	5	0	Absent	5	2	$5x10^2$	$5x10^3$	NA	NA	NA	NA	NA	NA	NA	NA
6.	Fermented meat products	5	0	Absent	5	0	Absent	5	2	$5x10^2$	$5x10^3$	NA	NA	NA	NA	NA	NA	NA	NA
7.	Dried/dehydrated meat product	5	0	Absent	5	0	Absent	5	2	$5x10^2$	$5x10^3$	NA	NA	NA	NA	NA	NA	NA	
8.	Cooked Meat Products	5	0	Absent	5	0	Absent	5	1	$1x10^2$	$1x10^3$	NA	NA	NA	NA	5	0	Absent	
9.	Canned/ Retort pouch Meat Products	5	0	Absent	5	0	Absent	5	0	Absent		5	0	Absent		5	0	Absent	
	Test Methods[3]	**IS: 5887 Part 3/ ISO 6579**			**IS: 14988, Part 1 &2/ISO 11290-1 & 2**			**ISO 15213**				**IS:5887, Part 4 or ISO 17919**				**ISO 10272-1&2**			

NA- Not Applicable

[1] **Definition of meat and meat products**:

Definition of animal, carcass , meat food product and slaughter house are the same as provided in FSS (Food Products Standards and Food Additives) Regulations 2011. Additionally the following definitions apply for the purpose of this regulation.

- **Canned/Retorted meat product:** Meat product packed in hermetically sealed containers which have been heat treated after sealing to such an extent that the product is shelf stable.
- **Chilled meat**: Fresh meat which has been washed with potable water and kept between 0-7°C.

Table-2B: Microbiological Standards for Milk and Milk Products – Food Safety Criteria

Sr. No	Product Description1	Salmonella sp.				*Listeria monocytogenes*				*Bacillus cereus*				Sulphite Reducing Clostridia (SRC)				*Enterobacter sakazakii (Cronobacter sp.)*			
		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)	
		n	c	m	M	n	c	m	M	n	c	m	M	n	c	m	M	n	c	m	M
1	Pasteurized/boiled milk/ Flavored Milk	5	0	Absent/25 ml	NA	5	0	Absent/25ml	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	Pasteurized Cream	5	0	Absent/25g	NA	5	0	Absent/25g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	Sterilized milk /UHT milk / Evaporated Milk	Sterilized /UHT milk products shall comply with a test for commercial sterility as per IS: 4238 (Appendix C or Appendix D)																			
4	Sterilized/ UHT Cream	Sterilized/UHT cream product shall comply with a test for commercial sterility as per IS : 4884																			
5	Sweetened Condensed Milk[5]	5	0	Absent/25g	NA	5	0	Absent/g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	Pasteurized Butter[2]	5	0	Absent/25g	NA	5	0	Absent/g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7	Milk Powder; SMP; PSMP; Dairy Whitener; Cream Powder ; Ice Cream Mix Powder; Lactose; Whey based Powder; Butter Milk Powder; Casein Powder	5	0	Absent/25g	NA	5	0	Absent/g	NA	5	3	$5x10^2$/g	$1x10^3$/g	5	3	50/g	$1x10^2$/g	NA	NA	NA	NA
8	Infant Milk Food, Infant Formulae, Infant Milk Substitutes	60	0	Absent/25g	NA	10	0	Absent/25g	NA	5	2	$1x10^2$/g	$5x10^2$/g	5	2	10/g	$1x10^2$/g	30	0	Absent/10g	NA
	Follow Up Formula	15	0	Absent/25g	NA	10	0	Absent/25g	NA	5	2	$1x10^2$/g	$5x10^2$/g	5	2	10/g	$1x10^2$/g	NA	NA	NA	NA

Sr. No	Product Description1	Salmonella sp.				*Listeria monocytogenes*				*Bacillus cereus*				Sulphite Reducing Clostridia (SRC)				*Enterobacter sakazakii (Cronobacter sp.)*			
		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)		Sampling plan		Limit (cfu)	
		n	c	m	M	n	c	m	M	n	c	m	M	n	c	m	M	n	c	m	M
	Cereal Based Complimentary Food	15	0	Absent/25g	NA	10	0	Absent/25g	NA	5	2	$1x10^2$/g	$5x10^2$/g	5	2	10/g	$1x10^2$/g	NA	NA	NA	NA
9	Ice Cream, Frozen Dessert, Milk Lolly, Ice Candy	5	0	Absent/25g	NA	5	0	Absent/g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10	Processed Cheese/ Cheese Spread	5	0	Absent/25g	NA	5	0	Absent / 25g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
11	All other cheeses categories including fresh cheeses / Cheddar / Cottage /Soft /Semi Soft etc	5	0	Absent/25g	NA	5	0	Absent/25 g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12	Fermented Milk Products	5	0	Absent/25g	NA	5	0	Absent/g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
13	Paneer/ Chhana/ chhana based sweets	5	0	Absent//25g	NA	5	0	Absent/g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
14	Khoa/ Khoa based sweets	5	0	Absent/25g	NA	5	0	Absent/g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	Test Methods[7]	IS 5887 : Part 3/ ISO : 6579				IS 14988 : Part 1/ ISO: 11290-1				IS 5887 (Part 6) /ISO:7932				ISO : 15213				ISO/TS 22964			

NA- Not Applicable

[1]Microbiological standards shall also be applicable for proprietary dairy foods depending on their analogy as determined by FSSAI with the product categories specified in **Table 2A and 2 B**

[2]The microbiological specifications for ripened butter are the same as for pasteurized butter excluding the requirements of Aerobic Plate Count.

[3]The yeast and mold count of 50/g as specified in dried product categories shall be applicable only to casein powder

[4]For products in this category (Infant Milk Food, Infant Formulae, Infant Milk Substitute), the *enterobacteriaceae* shall be tested. The microbiological criteria applicable is n=10; c=2; m= Absent/10g; M=Not Applicable. Method of analysis is ISO 21528-1 and 21528-2, as appropriate.

3. Methods used for microbiological analysis of foods

The analysis of foods for the presence of both pathogenic and spoilage bacteria is a standard practice for ensuring food quality and safety. However, the advent of biotechnology has greatly altered food testing methods and there are numerous companies that are actively developing assays that are more specific, sensitive and faster than conventional methods in testing microbial contaminants in food. The last 20-30 years have seen many developments in rapid detection techniques and also the dawning of technologies, which were predicted to change our ways of detecting pathogenic and spoilage organisms in food. This is an ideal situation wherein rapid methods such as online monitoring system can be useful to quickly screen large number of samples and thereby enhancing the processing efficiency. The degree to which rapid methods and automation are accepted and used for microbiological analysis is determined by the range and type of testing required, volume throughput of samples to be tested, availability of trained laboratory staff and the nature of manufacturing practices.

Based on the Process Hygiene criteria and Food Safety criteria, two types of analysis are required to assess microbiological quality of foods:

1. Total Microbial Load – in limits (Enumeration Methods)
2. Specific pathogen or their toxins – Absent (Pathogen/ Toxin Detection Methods)

3.1.Traditional methods used for enumeration of microbes:

Traditional methods followed for enumeration of microorganisms include

a. Plate count methods: Including pour plate, spread plate method and drop plate method.
b. Membrane filtration technique: Used for liquid food in large volume or when very low number of microorganisms are expected in the liquid food samples.
c. Dye reduction tests: Usually used for milk samples
d. Direct microscopic count: using Neubaurer chamber
e. Most probable number (MPN): used often for microbiological quality of water

3.1.1. Standard Plate Count (SPC)

SPC is useful in determining the viable number of microorganisms in foods. The procedure consists of diluting the organisms in a series of sterile dilutions. The measured amounts of diluted organism are transferred by spread plating/ pour plating over the appropriate agar plates and incubated for 24-48 h. Thereafter plates are examined and numbers of colonies are counted to calculate the number of viable cells or colony forming units per unit volume of the food material. The disadvantages of the method are that the technique is cumbersome, material intensive, technically demanding and time consuming.

Although, conventional methods are the gold standard in microbiological evaluation, traditional methods pose several challenges viz. i. Growth of fastidious pathogens - Delay in cultivation - takes more time ii. Non-culturability of certain organisms iii. Maintenance of viability iv. Hazardous to propagate in laboratory and v. Technical Expertise & Cost. Molecular methods on the other hand have several advantages including i. Faster and simpler ii. Increased sensitivity and specificity iii. Better adapted to instrumentation - Decrease the need for manpower iv. Identification of epidemiologically important strains. Therefore, recent research focus has been on developing rapid methods for detection of microbial pathogens and quantification of microbial load.

3.1.2. Most Probable Number (MPN)

The method was introduced by McCrady in 1915. This is a qualitative method for determination of the presence of coliforms in potable water. The selective medium used is MacConkey's medium which contains bile salt for inhibiting growth of non-intestinal lactose fermenting bacteria. Since the method is statistical in nature, MPN results are generally higher than SPC. The test can be performed in two formats- three tube and five tube method. The advantages of the MPN method include: 1. it is a simple technique; 2. good agreement between results from different laboratories; 3. identification of specific microbial group is possible by the use of appropriate selective and differential medium. Disadvantages of the test are the requirement for large number of glasswares / plasticwares and lack of precision.

3.1.3. Dye reduction Methods

Dye reduction test involve the use of redox dyes like methylene blue to determine the quality of milk. Methylene blue is reduced and loses its color in the presence of actively growing bacteria. The time taken for the reduction of methylene blue is inversely proportional to the number of viable bacteria. The shorter the methylene blue reduction time poorer is the quality of the milk. The advantages of the method are: 1. it is a simple and rapid method for grading bulk supplies of raw milk; 2. it is an inexpensive method; 3. no skilled personnel are needed to perform the test. Disadvantages of the test are: 1. it does not indicate the type of the organism involved in contamination and 2. there may be variations in count due to the degree of bacterial metabolism.

3.1.4. Direct Microscopic count (DMC)

Another quick and precise method for determination of microorganisms in liquid foods is the use of haemocytometer or Neubauer counting chamber. The method is quick but requires expertise. In the method appropriately diluted samples are transferred on the haemocytometer using a Pasteur pipette and counting of the microorganisms is directly carried out under the microscope. The haemocytometer has a grid system containing number of squares (25 large squares). The number of microorganisms present in the large square are counted and multiplied with the factor for large square and dilution factor to determine the total number of microorganisms in the sample. The advantages of the method are: 1. it is rapid and simple method; 2. cell morphology of the contaminating microorganism can be seen. Among its disadvantages are: 1. it is microscopic method and therefore is labor intensive; 2. both viable and nonviable cells are enumerated; 3. food particles interfere with the microbial counts; and 4. DMC counts are invariably higher than counts by SPC.

3.2. Rapid methods used for enumeration of microbes:

Rapid Methods for enumeration of microbes include a. ATP Bioluminescence; b. direct epifluorescent filter technique (DEFT) and c. electrical impedance-based methods.

3.2.1. Electrical Impedance

Impedance is the apparent resistance in an electric circuit to the flow of alternating current corresponding to the actual electrical resistance to a direct current. When microorganisms grow in culture media, they metabolize substrates of low conductivity into products of higher conductivity and thus decrease the impedance of the media. In general, impedance methods measure changes with the conductance of the growth medium. Conductance generally increases from 10 to 100% during growth, apparently from the increase in ion pairs as a result of metabolic activity. When the impedance of broth cultures is measured, the curves are reproducible for species and strains, and mixed cultures can be identified by use of specific growth inhibitors. The

technique is capable of detecting as low as ten to one hundred cells. Impedance has been widely used to monitor the overall microbial quality of various foods like vegetables, creams, raw milk, ground meat and other foods. Also, it is a rapid method to detect coliforms and fecal coliforms in meats. The method can also be used to predict shelf life of pasteurized milk and detection of spoilage organisms in beer fermentation. Yeasts growing in wort caused an increase in impedance while bacteria caused a decrease. Cell populations of 10^5-10^6/ml can be detected in 3-5 h; and 10^4-10^5/ml in 5-7 h. The times noted are required for the organisms to attain a threshold of 10^6-10^7 cells/ml.

3.2.2. ATP Measurement

Adenosine-triphosphate (ATP) is the primary source of energy in all living organisms. It disappears within 2 h after cell death and the amount per cell is generally constant, with values around 4 x 10^4 M ATP/10^5 cfu of bacteria. One of the simplest ways to measure ATP is by use of the firefly luciferin-luciferase system. In the presence of ATP, luciferase emits light, which is measured with a liquid scintillation spectrometer / luminometer. The amount of light produced by firefly luciferase is directly proportional to the amount of ATP added. This is a rapid method for assessing biomass in activated sludge and estimation of microorganisms in foods. The major problem that has to be overcome for food use is the removal of non-microbial ATP and other problems like one yeast strain was found to contain 300 times more ATP than the average for bacterial cells.

3.3. Methods of pathogen detection

Conventional methods for the detection and identification of microbial pathogens rely mainly on microbiological, biochemical and serological methods which include culture of the target organism, colony counting followed by biochemical and serological testing for final confirmation. These methods are sensitive, inexpensive and give both qualitative and quantitative information of the microorganisms present in food. However, they are disadvantageous as time taken for final confirmation the organism is usually high. Most of the traditional methods used for the detection of pathogenic bacteria involve the 5 basic steps: pre-enrichment, selective enrichment, selective plating, biochemical testing and serological testing. Therefore, conventional methods may take several days to give confirm identity of the microorganism as they rely on the ability of the organisms to multiply to visible colonies. Moreover, media preparation, handling of suspected samples and their processing are labor intensive and technically demanding. Conventional culture methods are generally regarded as the gold standard because culture methods remain the most reliable and accurate techniques for microbial detection. Although the culture-based methods are found to be standard microbiological techniques to detect

the single bacteria, amplification of the signal is required through growth of a single cell into a colony.

Any modification that reduces the time taken in the confirmation of the microorganism can technically be called rapid method e.g. detection of *Listeria monocytogenes* performed in a two-step cultural enrichment process took on an average one week until the biochemical identification of the *L. monocytogenes* suspected colony is completed, however, the ALOA® method (AES Laboratoire), which uses a chromogenic medium in conjunction with a Listeria mono-disk for the detection of *L. monocytogenes*, can reduce detection time down to 3 days.

4. Constraints in food microbiological analysis

Microbiological analysis of food, especially for particular pathogenic species remains a challenging task for virtually all assays and technologies. The problems may be due to the fact:

a. Bacteria in food materials are not uniformly distributed.
b. Heterogeneity of food matrices.
c. Complex composition containing ingredients such as proteins, carbohydrates, fats, oil, chemicals, preservatives etc.
d. Difference in the physical form of food e.g. powder, liquid, gel, semisolid or other forms.
e. Difference in viscosity due to fats and oils, which may interfere in proper mixing.
f. Presence of spoilage microbes which do not cause health risk but their presence often interferes with the selective isolation and identification of specific pathogens, which are usually present in low numbers in food.

5. Problems with conventional methods:

a. Cultivation-based methods are insensitive for detecting some non-culturable organisms.
b. Conventional methods are limited to pathogens with known growth requirements.
c. Poor discrimination between microbes with common behavioural features. Temperature of incubation used not conducive for all types of organisms. Visual appearance of micro organisms is non-specific.
d. Detection of slow-growing organisms takes weeks.
e. A number of viable microorganisms cannot be cultivated
f. A single media not sufficient to support all types of microbes.

6. Need for Rapid Methods of Pathogen Detection

The food industry is in need of more rapid methods which are sensitive for the following reasons:

a. To provide immediate information on the possible presence of pathogen in raw material and finished products.
b. Low numbers of pathogenic bacteria are often present in complex biological environment along with many other non-pathogenic organisms.
c. The presence of even a single pathogenic organism in the food may be an infectious dose (for some pathogenic microorganisms).
d. For monitoring of process control, cleaning and hygienic practices during manufacture.
e. To reduce human errors and to save time and labor cost.

7. Rapid Methods for Detection of Pathogens in Foods

Advances in biotechnology have led to the development of a diverse array of assays for detection of food pathogens and have significantly reduced the assay time. These assay procedures include nucleic acid-based assays, DNA probes and biosensors etc.

7.1. Nucleic Acid Based Assays

Nucleic acid-based assays including nucleic acid hybridization and nucleic acid amplification techniques offer more sensitivity and specificity than culture-based methods. In addition, these methods lead to drastic reduction in the time for getting results. Many of these methods have achieved automation thus facilitating their application as routine screening assays. The essential principle of nucleic acid-based assays is the specific formation of double stranded nucleic acid molecules from two complementary single stranded molecules under defined physical and chemical conditions. Many nucleic acid-based assays have been developed in the recent years as mentioned below.

7.2. DNA probe-based detection systems

A DNA probe is a short single-stranded sequence of nucleotide bases, usually14-40 bases long which will bind to specific regions of single-stranded target DNA sequences. The homology between the target and the DNA probe sequence results in stable hybridization. Hybridization is monitored by labelling probes. Labeling of probes is done by attaching or incorporating compounds into the probe that can be detected visually or chemically. Isotopes such as ^{32}P can be incorporated into the structure of the probe. Enzymes such as alkaline phosphatase (AP) or horseradish peroxidase (HRP) are often linked to the probe via a chemical linkage and hybridization can be detected visually following addition of substrates. Fluorescently labeled compounds such as fluorescein isothiocyanate can also be attached directly to probes.

7.3. DNA Micro Arrays (Gene Chip Technology)

Microarrays or gene chips provide a miniaturized system for the simultaneous analysis of hybridization of fluorescent-labeled single strand nucleotide chains to an array of oligonucleotide probes immobilized on a support such as glass or a synthetic membrane. PCR amplification is often used prior to hybridization to increase sensitivity of detection. DNA microarrays may be very useful for detecting multiple microbes simultaneously on a single glass slide. The complexity of the food matrix is major drawback for microarrays to be used as a detection method. However, the technique of microarrays has evolved and become more accessible for application in routine food diagnostics. Recently, a microarray system, for *Salmonella* detection has been brought to the market aiming at identification of the most common serovars of *Salmonella enterica*. Starting from a presumptive *Salmonella* colony, results on the serotype/ genotype of *Salmonella* are obtained within few hours. Development of this approach is continuing at a rapid pace and for microbiologists, this technology will be one of the major tools in the near future.

7.4. PCR- based detection of food pathogens

Polymerase Chain Reaction (PCR) has emerged as the most powerful molecular biology technique in the area of diagnostics. It is now being increasingly used for monitoring of foods for potential foodborne pathogens, so that the safety of these foods could be ensured. Using PCR, the target DNA sequence can be selectively amplified, thus increasing the amount of target available for detection. The PCR technique is a three-step process: 1. denaturation of double stranded DNA into single strands; 2. annealing of short complementary oligonucleotides (primers) to the target DNA sequence to be amplified, and 3. extension of primers using a thermostable DNA polymerase enzyme (e.g. Taq polymerase). A typical amplification of 30-40 cycles results in million-fold multiplication of the targeted DNA. Theoretically, the DNA from the single cell would be detectable following PCR amplification. One of the crucial features of the PCR is the possibility of direct analysis of food without essentially needing enrichment. Construction of the PCR assay requires nucleotide sequence information and knowledge about the chosen target gene to ensure specificity and sensitivity. By using multiplex PCR, it is now possible to simultaneously detect more than one foodborne pathogen in the suspected samples and the results are available in less than 24 h.

Nucleic acid-based assays are supposed to be highly sensitive and specific if suitably designed and optimized. Rapid test kits have been developed and now commercially available for detection of foodborne pathogens from various reputed commercial vendors. Virulence associated genes are commonly targeted for the detection of specific pathogens in foods. Limitations of end-point PCR include short dynamic range (< 2 logs), low resolution, non-automated, only size-based

discrimination, results are not expressed as numbers, ethidium bromide for staining is not very quantitative and requirement for post PCR processing.

7.5. Real-Time PCR

Real-time polymerase chain reaction also called real time quantitative PCR (qPCR) or kinetic polymerase chain reaction, is a laboratory technique in which amplification and simultaneous quantification of a targeted DNA can be done. The procedure follows the general principle of polymerase chain reaction. Its key feature is that the amplified DNA is detected as the reaction progresses in real time. The quantity can be either an absolute number of copies or a relative amount when normalized to DNA input or additional normalizing genes. Various chemistries are available including, SYBR Green dye (a fluorescent dye that intercalate with any double-stranded DNA), hydrolysis probes (e.g. Taqman probes) and hybridization probes (e.g. molecular beacons, scorpion probes). This is a new approach compared to standard PCR, where the product of the reaction is detected at its end. Real-time PCR allow for the detection of PCR amplification during the early phases of the reaction. Measuring the kinetics of the reaction in the early phases of PCR provides a distinct advantage over traditional PCR detection in which post PCR processing reduces sensitivity and increases time for the detection. With the ability to collect data in the exponential growth phase, the power of PCR has been expanded into applications such as: viral quantification, quantification of gene expression, array verification, drug therapy efficacy, DNA damage measurement, quality control and assay validation, pathogen detection and genotyping.

The most popular real-time PCR based system used in food authentication is the Qualicons BAX® detection system, which is a fast and accurate test for screening food and environmental samples for pathogens e.g. *E. coli* O157:H7, *Listeria monocytogenes*, *Enterobacter sakazakii*, *Salmonella* spp., *Campylobacter coli* etc. Advantages of using Real-Time PCR over traditional PCR include; 1. traditional PCR is measured at End-Point (plateau), while Real-time PCR collects data in the exponential growth phase; 2. an increase in reporter fluorescent signal is directly proportional to the number of amplicons generated; 3. increase dynamic range of detection; 4. no post-PCR processing is involved and therefore time for results is much less; 5. detection is capable down to a 2-fold change.

7.6. Loop Mediated Isothermal Amplification (LAMP)

Loop mediated isothermal amplification (LAMP) is a novel technique originally developed by Notomi et al. (2000). The principle of LAMP is auto-cycling strand displacement DNA synthesis in the presence of DNA polymerase with high strand displacement activity (*Bst* polymerase) under isothermal conditions between 60°C and 65°C. The final amplification products are mixtures of many different sizes of stem-loop DNAs with several inverted repeats of the target sequence and

cauliflower-like structures with multiple loops. The characteristics of this method include; 1. a set of two specially designed inner primers and two outer primers recognize six distinct sequences on target DNA, so the method is expected to amplify the target sequence with high specificity; 2. as the reaction proceeds under isothermal condition, no thermal cycler is needed and no time is lost in thermal change; 3. the amplification efficiency of LAMP is extremely high; 4. continuous amplification produces great amount of target DNA (to 10^9 level) as well as large amount of byproducts (white precipitate of magnesium pyrophosphate, within 30-60 min), allowing easy and rapid detection; 5. amplification products generated from LAMP can also be detected by gel electrophoresis, as for PCR; 6. specific amplification can be easily distinguished from nonspecific amplification by different ladder patterns on agarose gel and 7. the existence of the non target DNA and inhibition in LAMP mixture are less likely to affect the results. Therefore, LAMP constitutes a potentially valuable tool for rapid diagnosis of food-borne pathogens in either commercial or field labs.

8. Other Detection Methods:

8.1. Bacteriophage Based Methods

Bacteriophages are viruses infecting bacteria. Phages in general are extremely host-specific. Most bacteria can be infected by particular phages and it is common that a given phage can recognize and infect only one or a few strains or species of bacteria. The specificity of these phages is partly mediated by tail-associated proteins that distinctively recognize surface molecules of susceptible bacteria. Bacteriophages or proteins of bacteriophages have been included in various ways in detection methods for foodborne pathogens. The specific bacteriophage tail-associated proteins may be attached to paramagnetic beads to capture bacteria in suspension. The bacteria bead complex can be integrated in fast detection protocols. The Listeria Capture kit (Hyglos) can be integrated as part of a rapid detection method in a similar way as IMS. The specificity of the test is provided by the use of the antibodies during the IMS capture as well as by the use of a specific bacteriophage to lyse the cells. Results of the test, as such are obtained within hours although a prior enrichment may take 6-24 h depending upon the type of microorganism.

8.2. Fourier transform infrared spectroscopy (FT-IR)

Fourier transform infrared spectroscopy (FT-IR) is used to generate bacterial spectral scans based on the molecular composition of a sample and mainly consists of the infrared source, the sample and the detector. It is a non-destructive rapid method and sample identification depends on the available spectral library. When IR is absorbed or transmitted through the sample to the detector, it generates a scan or fingerprint profile. A library of spectral scans can be generated for different bacterial species and strains, which can be used for future comparison. This method requires transfer of cells (biomass) from the growth media to an IR reflecting substrate for

spectral collection. FT-IR has been used for classification or identification of several foodborne pathogens including *Yersinia, Staphylococcus, Salmonella, Listeria, Klebsiella, Escherichia, Enterobacter, Citrobacter*, etc. FT-IR photoacoustic spectroscopy was used for the identification of spores of several *Bacillus* species with 100% accuracy.

8.3. **Solid Phase Cytometry (SPC)**

SPC is a novel technique that allows rapid detection of bacteria at single cell level, without the need for growth phase. The short time detection inherent in this approach is of considerable advantage over conventional plating techniques especially for slow growing bacteria. SPC combines aspects of flow cytometry and epifluorescene microscopy. The microbes are isolated from their matrix from membrane filter, fluorescently labeled with argon laser excitable dye and automatically counted by laser scanning device. During 3 min scanning process the entire membrane filter surface is scanned yielding a theoretical detection limit of one cell per membrane filler. During scanning two photo multiplier tubes with wavelength 500 to 530 nm (green) and 540-585 nm (amber) detects the fluorescent light emitted by labeled cells. The signals are processed with software which differentiate between viable signals (target cells) and background noises (electronic noise and fluorescent particles). Scanned results are displayed as primary and secondary maps. Actual nature of each fluorescent spot can be further examined by epifluorescent microscope.

8.4. Electronic nose

This system comprises of sophisticated hardware with sensors, electronics, pumps, flow controllers, software, data preprocessing and statistical analyzer. In microbiology the smell of the cultural bacteria often provides a clue to the identification of the organisms present which requires skill. Large amounts of different gaseous components are released from substrates contaminated with spoilage organisms. The traditional approach has been sample extraction followed by gas chromatography, which is tedious and requires some knowledge of the molecules involved. Electronic nose can be applied either in monitoring factors influencing spoilage or factors indicating spoilage. The samples from headspace are passed into the sensor which contains several odor sensors. A computer collects the sensory signals from the sensors where first pretreatment of data is done. The data are further analyzed by software and the results displayed. Several researches are underway to have a clear understanding of the principle of this technique in detection of spoilage and pathogenic organisms.

9. Immunological Methods

Enzyme linked immunosorbent assay (ELISA) and Enzyme linked fluorescent as says (ELFA)

ELISA couples an immunoassay with an enzyme assay. In most of the foodborne pathogen detection methods, a sandwich format is used utilizing two antibodies to trap the target antigen followed by the addition of an enzyme-labelled secondary antibody. In the final step a substrate is added that the enzyme can convert to a detectable signal.

The ELISA detection itself only takes 2-3 h (Kumar *et al.,* 2008; Szabo *et al.,* 2008; Lilja and Hanninen, 2001; Croci *et al.,* 2001). Now-a-days, many ELISA tests are available as automated systems to reduce the hands-on time and improve reproducibility. While many ELISA-based methods rely on chromogenic substrates for end-point detection of the target antigen, ELFA employs fluorescence for endpoint detection (Sewell *et al.,* 2003).

9.1. Lateral Flow Assays

Lateral flow assays (LFAs) also known as immunochromatographic tests (ICTs) or strip tests have been a popular diagnostic platform as they are cheaper, user friendly and less time consuming. The main driver for their popularity has been pregnancy diagnostics and glucose monitoring kits available in the market. LFAs are the simplest to use of all the test formats simply requiring the user to place the test strip in the specimen or add sample directly onto it. The sample may be derived from a clinical case, food or environment. Now-a-days, LFAs are in use for the specific qualitative or semi-quantitative detection of one or more analytes (multiplex LFAs). Therefore, there is a growing demand for development of lateral flow assay devices for fast, accurate, reliable and economic detection of foodborne pathogens or their toxins.

LFAs detect the presence or absence of a target analyte in the sample. These are a form of immunoassay in which the test sample flows along a solid substrate via capillary action. A colored reagent then mixes with the sample and then transits the substrate encountering lines or zones pretreated with an antibody or antigen. Depending upon the analytes present in the sample, the colored reagent can become bound at the test line. Some LFA strips are available for detection of pathogens or their toxins in food from Merck-Millipore and Dupont.

9.2. **Flow cytometry (FCM)**

It is a powerful technique based on the same principle as immunofluorescence. The instrument detects fluorescent cells that are moving in a fluid stream past an optical sensor. The flow cytometer measures the light scattered or the fluorescence emitted by the cells as they pass through the laser beam. The light energy is converted into an electrical signal by photomultiplier tubes. FCM is sensitive, does not require culturing or enrichment procedures and can be both qualitative and quantitative

(Attfield *et al.,* 1999). It can be used as a tool to determine product quality. FCM combined with immunofluorescent labelling has been used to detect *L. monocytogenes* and other pathogenic bacteria in dairy products (Gunasekera *et al.,* 2002).

10. Biosensors

A biosensor is an analytical device typically consisting of a bio-recognition component, transducer, a signal amplifier, processor and computer display. The recognition component, called a bioreceptor uses biomolecules to interact with the analyte of interest. This interaction is measured by the transducer which converts it in to digital signal which in turn gets amplified by the amplifier and finally displayed by the data processing unit/computer. Biosensing methods for pathogen detection are centered on four basic physiological or genetic properties of microorganisms: i. metabolic patterns of substrate utilization, ii. analysis of phenotypic expression of signature molecules by antibodies, iii. nucleic acid analysis and iv. analysis of interaction of pathogens with eukaryotic cells. However, antibody-based methods are the most popular because of their versatility, convenience and relative ease in interpretation of the data. Majority of biosensors use antibody for capture and detection of the target analyte.

Biosensors can be classified according to common types of bioreceptor interactions involving: antibody/antigen, enzymes, nucleic acids/DNA, cellular structures/cells, or biomimetic materials. Biosensors can also be classified by their biotransducer type. The most common types of biosensors are i. electrochemical biosensors (amperometric, potentiometric, impedimetric), ii. optical biosensors, iii. electronic biosensors, iv. piezoelectric biosensors, v. gravimetric biosensors, vi. pyroelectric biosensors vii. Surface Plasmon Resonance (SPR) Biosensor, viii. Cell based biosensors, ix. DNA based biosensors x. Bioluminescence biosensors (ATP bioluminescence and Bacterial bioluminescence) and xi. Immunosensors.

Potential applications of biosensors include: i. Glucose monitoring in diabetes patients (historical market driver) and other medical health related targets ii. Environmental applications e.g. the detection of pesticides and river water contaminants such as heavy metal ions, iii. Remote sensing of airborne bacteria e.g. for countering bioterrorism threats, iv. Detection of pathogens, v. Determining levels of toxic substances before and after bioremediation, vi. Determination of drug residues in food, such as antibiotics and growth promoters, particularly in meat and honey, vii. Drug discovery and evaluation of biological activity of new compounds 8) Detection of toxic metabolites such as mycotoxins etc.

A circulating-flow piezoelectric biosensor, based on gold nanoparticle amplification and verification method, was used for real-time detection of a foodborne pathogen, *Escherichia coli* O157:H7. The University of Florence has developed a piezoelectric biosensor, which detects the bacteria *Listeria monocytogenes*. The biosensor was applied for the detection of *Listeria* spp. diluted in milk and found to be as sensitive as conventional methods with results obtained in less than 15 minutes.

Detection with antibodies, which are specific for a particular microorganism, or toxin is the basic approach utilized in immunosensors. In recent years, DNA-based biosensors have been developed for the detection of pathogens. Wang (2002) successfully developed novel genosensor for *Cryptosporidium, E. coli, Giardia* and *Mycobacterium tuberculosis.* Biosensor technology is advantageous in significantly reducing time for assay, detecting much smaller amounts of target analyte with fewer false positives, high throughput and capability for automation.

11. Newer Technologies for Pathogen Identification

11.1. Matrix Assisted Laser Desorption Ionization-Time of Flight Mass Spectrometry (MALDI-TOF MS)

In the recent years MALDI-TOF MS has emerged as a potential tool for microbial diagnosis. In the MALDI-TOF MS, microbes are identified using either intact cells or cell extracts. The process is rapid, sensitive, and economical in terms of labor and costs involved. The technology has been readily used by for microbial identification. The limitation of the technology is that identification of organism is possible only if the spectral database contains peptide mass fingerprints of the type strains of specific genera/species of the target organism (Singhal *et al.,* 2015).

The method is technically simple and rapid. Bacterial colonies are removed from culture plates, mixed with an excess of UV-absorbing matrix, and dried on steel target plates. The dried preparations are exposed to laser pulses, resulting in energy transfer from the matrix to the non-volatile analyte molecules, with desorption (removal) of analyte into the gas phase. The ionized molecules are accelerated by electric potentials through a flight tube to the mass spectrometer, with separation of the biomarkers determined by their mass/charge ratio (m/z). The profile of biomarkers is then compared with profiles of a collection of well-characterized organisms (Murray, 2012). The most common reason an isolate is not identified is because it is not included in the database. As experience is gained with MALDI-TOF MS, it is expected that the database will be expanded to include a greater number of organisms.

MALDI-TOF MS offers the possibility of accurate, rapid, and inexpensive identification of microorganisms. Although, only limited work has been reported on the use of mass spectrometry to identify pathogens, the technique is rapidly picking up in the area of diagnostics.

11.2. Next Generation Sequencing (NGS)

Another revolutionary discovery in bioinformatics is next generation sequencing. This is a powerful new technology which enables generation of over one million DNA sequences per run, parallel analysis of multiple samples, detection of unknown pathogens in complex samples and is yet to widen its application in food pathogen detection (Adams *et al.,* 2009).

12. Limitations of Rapid Methods:

Almost all rapid methods are designed to detect a single target, which makes them ideal for use in quality control programs to quickly screen large numbers of food samples for the presence of a particular pathogen or toxin. A positive result by a rapid method however, is only regarded as presumptive and results must be further validated by a standard method. Although, confirmation may extend analysis by several days, this may not be an imposing limitation, as negative results are most often encountered in food analysis. Most rapid methods in food analysis still lack sufficient sensitivity and specificity for direct testing; hence, foods still need to be culture-enriched before analysis. Evaluations of rapid methods show that some perform better in some foods than others and *vice versa*. This can be attributed mostly to interference by food components, some of which can be especially troublesome for the technologies used in rapid methods. The specificity of DNA based assays is dictated by short probes; hence, a positive result, for instance with a probe or primers specific for a toxin gene, only indicates that bacteria with those gene sequences are present and that they have the potential to be toxigenic. But, it does not indicate that the gene is actually expressed and that the toxin is produced in the food implicated. Likewise, in *clostridial* and *staphylococcal* intoxication, DNA probes and PCR can detect only the presence of cells, but are of limited use in detecting the presence of preformed toxins. Currently, there are at least 30 assays each for testing for *E. coli* O_{157}:H_7 and for *Salmonella*. Such a large number of options can be confusing and overwhelming to the user.

13. Conclusion and Future Steps:

Early screening of food products is an important measure to prevent epidemics relating to foodborne pathogens. Hence, the present era demands highly sensitive, specific, rapid and cost- effective diagnostic assays for detection of pathogens. Conventional, immunological, and nucleic acid-based methods provide reliable results, but are slow and require specialized equipment and personnel. Flow cytometry is an effective detection method with potential for integration into the food inspection system, especially with the recent development of disposable microfluidic chips. Biosensors, notable for their speed, inexpensiveness, and minimal sample pre-treatment, are another emergence in the field of foodborne pathogen detection. However, biosensor performance, particularly in terms of sensitivity and specificity, is still unreliable. Further advancements must be made before biosensors are robust enough to be accepted as a standard in food microbiological testing. MALDI TOF-MS is another promising and upcoming technology however its popularization in routine diagnostic use shall take some time due to cost factors and up-dation of pathogen specific library.

As a rapid method is used more frequently, its benefits and limitations also become more apparent. Complex designs of these technologies coupled with the

complexity of food matrix, users must exercise caution when selecting rapid methods and to also evaluate these tests thoroughly under distinct testing situations or for assaying certain types of food. Technologies continues to advance at a great pace and next generation assays such as biosensors, DNA chips and MALDI TOF-MS already are being developed that potentially have the capability for near real-time and on-line monitoring of multiple pathogens in foods. As rapid methods are being used more frequently, its benefits and limitations also become more apparent.

****References can be requested from the authors****

Chapter-22

FSSAI Registration and Licensing for Animal Products Establishments

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1. Introduction

The Food Safety and Standards Authority of India (FSSAI) is a statutory body under the administration of the Ministry of Health and Family Welfare, Government of India. It regulates the manufacture, storage, distribution, sale, and import of food articles, while also establishing standards to ensure food safety. The FSSAI was established by the Food Safety and Standards Act, 2006, which consolidated all former acts and orders related to food safety that were previously handled by various ministries and departments.

For animal products such as dairy and meat products, which are often susceptible to contamination and spoilage, FSSAI's oversight is critical in maintaining public health and ensuring the quality of these products.

As per Food Safety and Standards Act, all Food Business Operators (FBOs) in the country should be registered or licensed in accordance with the procedures laid down in Food Safety And Standards (Licensing And Registration of Food businesses) regulation, 2011.

The condition whether FBOs should apply for registration or State License or Central License depend on the following factors (Refer the below mentioned table)

- ✓ Annual turnover of the establishment
- ✓ Capacity of the establishment
- ✓ Type of products manufactured
- ✓ Kind of Business

Kind of Business	**Criteria**	**License/ Registration**	**Fee Per Annum**

Petty Food Business Operators Manufactures or sells any kind of food by himself/herself, Petty retailer, hawker, itinerant vendor, temporary stall, Thela, Sweets Shop, Juice Stalletc. e.g Gol gappa stall, fruits/vegetables vendors, snacks stall, Tea Stall, Samosa, Bread pakoda, retail shops, Temporary Food Stalls like Chinese food stall, South Indian Food etc. **Temporary or fixed stall** or food premise involved in preparation, storage, distribution and sale of food products that can be served as a snacks/ tea/coffee and similar variants. **Hawker** - Selling packaged or freshly prepared food by travelling (usually on foot or movable carts) from one location to other	Annual Turnover upto Rs. 12 Lacs	Registration	Rs. 100
Dairy Units including Milk Chilling Units Dairy processing means handling, processing, manufacturing, packing, storing, distribution & transportation of milk and milk products. Note: Registration for Petty Milkman, Milk Vendors, License for rest according to Eligibility criteria	More than 50,000Liters of Milk per day More than 2500 MT of Milk Solid Per annum	Central License	Rs. 7500
	10001 – 50,000 Ltrs of Milk per day 501 MT – 2500 MT of Milk Solids per annum	State License	Rs. 5000
	501 – 10,000 Ltrs of Milk per day 2.5 MT – 500 MT of Milk Solids per annum	State License	Rs. 3000
	Upto 500 Ltrs of Milkper day Upto 2.5 MT of Milk Solids	Registration	Rs. 100

	per annum		
	1-2 MT per day	State License	Rs. 5000
	Below 1 MT per day	State License	Rs. 3000
	Turnover upto Rs. 12Lacs per annum	Registration	Rs. 100
Slaughtering House Slaughtering means a process of transporting, stunning, butchering, dressing, processing, storing & distribution of live animal/poultry birds	Large Animals: Morethan 50 Small Animals: More than 150 Poultry Birds: More than 1000	Central License	Rs. 7500
	Large Animals: 3 to 50 Small Animals: 11 to 150 Poultry Birds:	State License	Rs. 2000
	51 to 1000		
	Large Animals: 2 Small Animals: 10 Poultry Birds: 50	Registration	Rs. 100
Meat Processing Meat processing means further processing of slaughtered animals/poultry birds into meat & meat products, packaging, storing & transportation of meat & meat products. Fish processing means handling, processing of fish, manufacturing of fishproducts, packing, storing, distribution & transportation of fish and fish products.	More than 500 Kg Meat per day or More than 150 MT Meat per annum	Central License	Rs. 7500
	Upto 500 Kg Meat per day or Upto 150 MT Meat per annum	State License	Rs. 3000
	Turnover upto Rs. 12Lacs per annum	Registration	Rs. 100
	Production Capacity: 101 Kgs/Ltrs – 1 MT per Day All Grains,Cereals, PulsesMilling units without any limit on Production Capacity	State License	Rs. 3000
	Production Capacity:1MT – 2 MT per Day	State License	Rs. 5000

	Turnover upto Rs. 12 Lacs per annum Or Production capacityupto 100 Kgs/Ltrs per day	Registration	Rs. 100
Proprietary Food	No restriction onproduction capacity	Central License	Rs. 7500
Non-specified food "Non-specified food" means any food other than proprietary food or food ingredients, including additives, processing aids and enzymes for which standards have not been specified in any regulation made under the Act.	No restriction onproduction capacity	Central License	Rs. 7500
For Other Categories kindly refer	Food Safety And Standards (Licensing And Registration of Food businesses) regulation, 2011		

2. **Procedure and timeline for the grant of Licence or Registration of Animal Food Establishment**
   - In order to streamline the process of License or Registration application process online platform was developed by FSSAI called as Food Safety Compliance System (FoSCoS) through which FBOs can apply for License or Registration

     ✓ **<u>Registration of Petty Food Business</u>**
   - The Registering Authority shall consider the application of Registration and may either grant registration or reject it with reasons to be recorded in writing or issue notice for inspection, within 7 days of receipt of an application for registration.
   - In the event of an inspection being ordered, the registration shall be granted by the Registering Authority after being satisfied with the safety, hygiene and sanitary conditions of the premises as contained in Part I of Schedule 4 within a period of 30 days.

- If registration is not granted, or denied, or inspection not ordered within 7 days or no decision is communicated within 30 days as provided, the petty food manufacturer may start its business, provided that it will be incumbent on the Food Business Operator to comply with any improvement suggested by the Registering Authority even later.
- The Registering Authority shall issue a registration certificate and a photo identity card, which shall be displayed at a prominent place at all times within the premises or vehicle or cart or any other place where the person carries on sale/manufacture of food in case of Petty Food Business.

✓ **<u>License for food business</u>**

- A license shall be issued by the concerned Licensing Authority within a period of 60 days from the date of issue of an application ID number.
- If, upon scrutiny of the application within 15 days from the date of receipt of the application, the concerned Licensing Authority requires any additional information with respect to an application or if the application is incomplete, the Licensing Authority shall inform the applicant in writing, to furnish such additional information or complete the application, as the case may be, within 30 days from such notice. In case the applicant fails to furnish the required information within the stipulated time of 30 days, the application for license shall stand rejected.
- If, upon scrutiny of the application within 15 days from the date of receipt of the application, the concerned Licensing Authority requires any additional information with respect to an application or if the application is incomplete, the Licensing Authority shall inform the applicant in writing, to furnish such additional information or complete the application, as the case may be, within 30 days from such notice. In case the applicant fails to furnish the required information within the stipulated time of 30 days, the application for license shall stand rejected.
- On the receipt of a complete application including the additional information if asked for, the Licensing Authority shall issue an Application ID number to each applicant that will be referred to in all future correspondence between the Licensing Authority and the applicant.
- After the issue of Application ID number the Licensing Authority may direct the Food Safety Officer or any other person or agency specially designated for such functions to inspect the premises in the manner prescribed by the Food Safety and Standard Authority of India in accordance with these Regulations. Such Inspecting Officer or person may issue a notice to the applicant, if it deems fit, guiding food business operator on necessary steps to be taken or changes or alteration to be made in the premises in order to ensure general sanitary and hygienic conditions as specified in Schedule 4 {Refer Food Safety and Standards (Licensing and Registration of Food businesses)}. The applicant shall carry out

the required steps, changes or alterations and intimate the Licensing Authority within 30 days or such period as may be allowed by the Licensing Authority.

- Within a period of 30 days from receipt of an inspection report excluding the time taken by the applicant in complying with the advice, if any, given in the inspection report and verification thereof, the concerned Licensing Authority shall consider the application and may either grant license or reject the application.
- Provided that before refusing license, an applicant shall be given an opportunity of being heard and the reasons for refusal shall be recorded in writing.
- The Licensing Authority shall issue a License, a true copy of which shall be displayed at a prominent place at all times within the premises where the Food Business Operator carries on the food business.

3. Commencement of Business

An applicant may commence his food business and the concerned licensing Authority shall not deny the applicant to commence such business if, from the date of making the completed application, a license is not issued within 60 days or the applicant has not received any intimation of inadequacy or inspection report indicating defects from the concerned Licensing Authority under Regulation.

4. Validity and Renewal of Registration and License

- A Registration or license granted under these Regulations shall be valid, for a period of 1 to 5 years as chosen by the Food Business Operator, from the date of issue of registration or license subject to remittance of fee applicable for the period and compliance with all conditions of license.
- Not later than 30 days prior to the expiry date indicated in the license, the applicant should apply for renewal otherwise a late fee of Rs 100 per day for each day of delay shall be paid in case of license.
- If licence or registration not renewed after 30 days of expiry, the Food Business Operator shall stop all business activity at the premises. The Food Business Operator will have to apply for fresh Registration or license as provided in Regulation.
- If the FBO continues to run his business without license or registration then he shall be penalized under FSS act 2006.

****References can be requested from the authors****

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