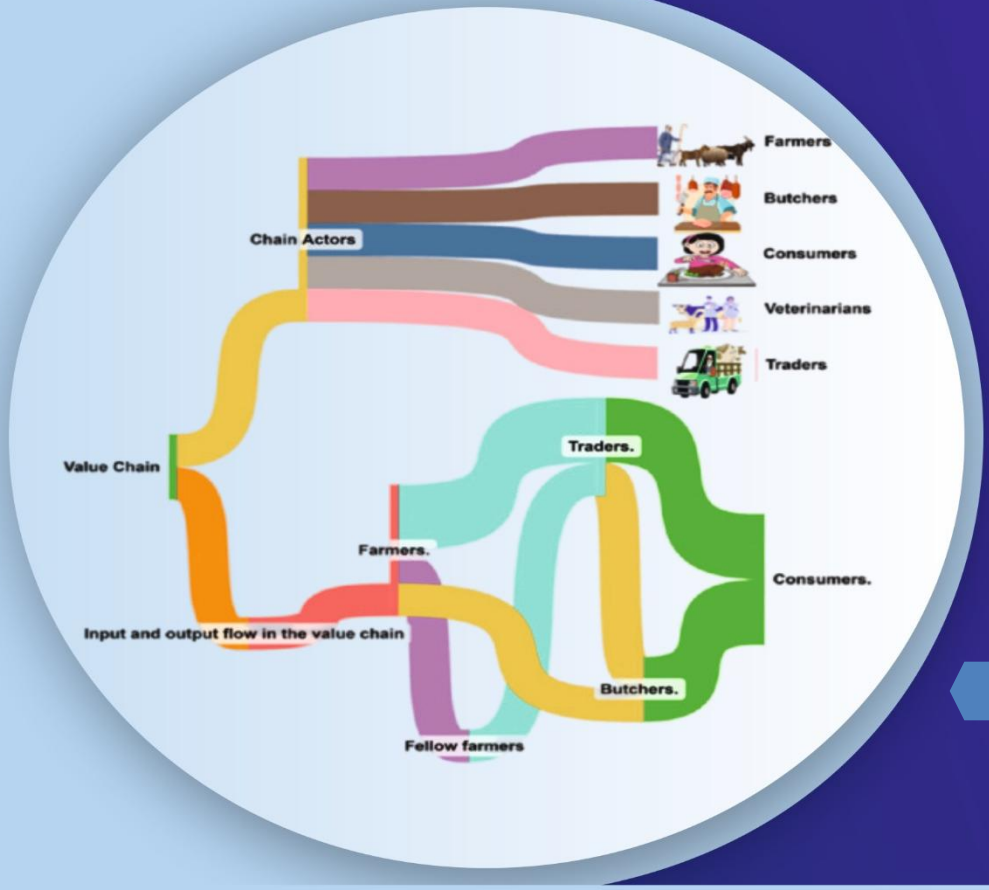
VALUE CHAIN ANALYSIS OF DIFFERENT LIVESTOCK FARMING: A MUST-KNOW FOR EXTENSION PERSONNEL



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Value Chain Analysis of Different Livestock Farming: A must-know for Extension Personnel

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This e-book is a compilation of resource text obtained from various subject experts of GADVASU, Ludhiana & MANAGE, Hyderabad, on "Value Chain Analysis of Different Livestock Farming: A must-know for Extension Personnel". This e-book is designed to educate extension workers, students, research scholars, academicians related to veterinary & animal husbandry extension about the insights to navigate and optimize every stage of the livestock value chain, enabling them to identify areas for improvement, and implement strategies to enhance efficiency and productivity. Neither the publisher nor the contributors, authors and editors assume any liability for any damage or injury to persons or property from any use of methods, instructions, or ideas 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 warranty for any error or omissions regarding the materials in this e-book.

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Value Chain Analysis of Different Livestock Farming: A must-know for Extension Personnel

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FOREWORD

In an era where the livestock sector plays a pivotal role in supporting rural livelihoods, enhancing food security, and contributing to national economies, understanding the intricacies of the livestock value chain is more important than ever for extension professionals. Extension personnel serve as the vital link between research, policy, and the farming community. Their role is not limited to transferring technologies or disseminating knowledge; it encompasses empowering farmers, fostering innovation, and enabling sustainable practices that add value to every step of the production process. This book captures the essence of value chain analysis, highlighting its importance as a strategic tool for extension officers to identify opportunities, address challenges, and ensure equitable and sustainable growth across the livestock sector.

This e-book, "*Value Chain Analysis of Different Livestock Farming: A Must-Know for Extension Personnel"* provides a concise yet comprehensive exploration of the livestock value chain, offering insights into production, processing, marketing, and consumer trends. It emphasizes the importance of collaboration among stakeholders and underscores how extension personnel can serve as catalysts for fostering partnerships, ensuring market access, and enhancing the competitiveness of livestock products in a rapidly evolving agricultural landscape.

I sincerely appreciate the joint efforts of Guru Angad Dev Veterinary and Animal Sciences University (GADVASU) and the National Institute of Agricultural Extension Management (MANAGE) in bringing this e-book to fruition. This e-book may serve as a valuable resource and inspire its readers to adopt a holistic perspective on livestock farming and encourage them to harness the potential of value chain analysis in transforming the sector.

I extend my heartfelt congratulations to the authors and contributors for their dedicated efforts in bringing this critical topic to the forefront. May this e-book empower extension personnel to lead with knowledge and innovation, and to create a lasting impact on the lives of livestock farmers.

Dr. Parkash Singh Brar
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PREFACE

Livestock farming is a lifeline for millions of farmers, a cornerstone of rural development, and a vital contributor to global food security. In this dynamic and ever-evolving sector, understanding the value chain—from farm to fork—is not just an advantage; it is a necessity. This e-book, *Value Chain Analysis of Different Livestock Farming: A Must-Know for Extension Personnel*, is crafted with the vision of empowering extension professionals to address the challenges and seize the opportunities in livestock farming. By unravelling the complexities of the livestock value chain, this resource provides a holistic understanding of how each link—production, processing, marketing, and distribution—interconnects and influences the lives of farmers and consumers alike.

From unveiling the dairy value chain journey, which delves into the complexities of the dairy industry, to pigging out for prosperity, which uncovers the untapped potential of pig farming, this e-book explores the diverse realms of livestock farming with actionable insights. It further explores the poultry sector in wings to wealth and highlights the often-overlooked yet promising opportunities within goat farming in goat to great. Beyond the core livestock sectors, this e-book also explores crucial aspects that are key to strengthening the value chain, such as the role of farmer producer organizations (FPOs) and the transformative impact of unconventional ingredients.

This e-book is an outcome of collaborative online training program on “Value Chain Analysis of Different Livestock Farming: A Must-Know for Extension Personnel” conducted from July, 09-11, 2024. It will be an invaluable resource for extension professionals, offering practical insights and strategies that are essential for enhancing productivity, addressing challenges, and driving sustainable growth in the livestock sector.

The editors express sincere thanks to the Hon’ble Vice-Chancellor, Guru Angad Dev Veterinary and Animal Sciences University (GADVASU) for inspiration and encouragement in publishing this e-book. The financial aid provided by MANAGE, Hyderabad for this training program is duly acknowledged. We hope and believe that the suggestions provided in this e-book, will significantly contribute to enhancing the knowledge and effectiveness of all stakeholders in improving the overall management and sustainability of livestock farming.

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Chapter 1

Beyond the Barn: Unveiling the dairy value chain industry

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India has the largest dairy animal population in the world (GOI, 2019), and ranks first position in milk production across the globe; India contributes 25 per cent of global milk production. Livestock sector including dairy farming plays an important role in Indian economy, and is a source of income for our farmers. Based on the input use and market facilities, the dairy production system in India can be classified into four categories: (1) pastoral system (2) semi-intensive or crop-livestock production system (3) peri-urban dairying (4) intensive or industrial production system (Srivastava et al., 2015). There are some common as well as different activities (from production to sale) in aforementioned production system. There is a potential for further improvement in the dairy industry in India, however farmers are facing several challenges. Understanding and analysing challenges in the steps involve could be helpful to uplift the dairy industry, and value chain is a concept which could aid to face those challenges, fix associated issues and assess the interaction between the different actors involved in various activities of a value chain (dairy value chain).

There are several definitions of the value chain. The activities required to bring a product/service from conception to its different phases of production comprises value chain (Thompson, 1998). Value chain is a chain of activities from conception of a production to its final consumption (McCormick and Schmitz, 2001). Value chain thus helps to understand the supply chain, how it works, what are the challenges and issues, and how they could be fixed in order to maximize profits. It is to note that understanding and analyzing these steps help farmers not only to uplift the dairy sector but also support consumer to have safe milk and its products. In

addition, this aids to reduce the marketing risks (Birthal et al., 2017). Herein, we will discuss the important challenges and opportunities in the dairy value chain especially in term of animal and human health, which would be helpful to improve the dairy sector.

The primary activities of dairy value chain involve milk production, collection, transportation, processing as well as marketing. Supportive activities may involve human resource management and administration. Feed and fodder are considered as the most expensive component of the production system. Daily average requirement of green fodder/animal is 40-50 Kg; deficiency of fodder may lead to insufficient milk production due to nutritional deficiencies (Singh, 1998, Nagrale et al., 2015). To tackle the issue related to the dearth of fodder, a feed and fodder component was supplemented in the National Livestock Mission; this would be helpful to enhance the availability via several activities involving training farmers, organizing demonstrations, encouraging crop rotation etc. The dry fodder can also be utilised for feeding animals. The small-scale farmers (with no/limited land) may face dearth of dry fodders, or purchase it from the market, and this may prompt farmers to purchase dry fodder from the market. In addition, due to economic constraints the farmers prefer to make their own feed at the farm (Landes et al., 2014, Bakshi and Wadhwa, 2017). Majority of the sale and purchase of animals is not organized; animals can be sold/purchased without prior diagnoses of the prevalent infections which could lead to the spread among susceptible animals as well as humans (in case of zoonotic infections). Thus, there is a need to develop policies to regulate the aforementioned issue.

Female farmers are also involved in several activities, especially milking and feeding of animals, as well as manuring of the farm. Studies have shown that handling manure could be a potential risk of exposure to the *Brucella* spp., a zoonotic pathogen that impact both animal and human health (Yohannes et al., 2011, Mantur et al., 2007); other bacterial pathogens could also pose risks (Penakalapati et al., 2017). Farmers need to be educated about the hygienic and biosecurity practices while handling the animals' excreta as well as how to dispose of them properly. Disposal of carcass is another challenge. Dead animals are deskinned by the knackers and left in the open on the disposal site; carcasses are scavenged by animals and/ birds.

Veterinary services play a pivotal role in the dairy production system. Despite the fact the most of the services provided by the state veterinary services are free/with nominal fee, farmers do not avail those facilities as this may involve extra cost on the movement of animals to government hospitals and follow-up visits; thus, there is need for government policy interventions to resolve this issue (Chandel and Singh, 2015). Adoption of biosecurity measures by veterinarians, para veterinarians and animal handlers as well as farm workers is must to follow while involved in several activities in the farm, as this not only help to contain the infections, restrict pathogens entry to the farm but also aid to safeguard the health of workers. In nut shell, to improve dairy production, there is a necessity to reduce infectious diseases including zoonoses, enhance farmer economy as well as progress the animal welfare, dairy value chains would be helpful to find the gaps, challenges and opportunities to fix the same.

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Chapter 2

White Gold: From Farm to Fridge, Unravelling Milk Journey

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Globally, milk production has seen a remarkable increase, with a 63% rise since 1990. This growth reflects advancements in dairy farming techniques, improved animal breeds, and better management practices. India is the major player in world milk production although; the United States, China, and Brazil also play vital roles in global milk production, focusing on large-scale operations and technological innovations. The rise of dairy section as a whole around the world is certainly due to following reasons: a) Innovations in milking equipment, herd management, and feed quality have boosted production efficiency. b) Supportive policies and subsidies for farmers enhance production capabilities and market access. c) Rising demand for dairy products in emerging economies drives production growth, encouraging investment in the dairy sector. However, at same time, impacts such as changing weather patterns affect feed availability and animal health, influencing milk yield wherein these challenges demand efficient use of water and land resources for sustainable dairy farming practices.

India stands out as the world's largest milk producer, contributing significantly to this growth with an annual output of 231 million tons (BAHS, 2023). India's dairy sector is characterized by its vast network of smallholder farms, with around 80 million households involved in milk production. India provides land to the 10.2%of the world’s livestock population which is one of the primary sources of nutrition and food security in the country. India ranks 1st in the world in terms of total milk production with 230.58 million tonnes of milk production during 2022-23 (FAO, 2023 & BAHS, 2023). A notable aspect is the cooperative model, which includes approximately 22% of milk producers. Dairy cooperatives play a crucial role, procuring

over 51 million kg of milk per day. These cooperatives ensure fair pricing and market access for farmers, fostering a sustainable livelihood.

Punjab is a major player in India's milk production, with yields surpassing the national average. The state's dairy sector contributes 30.64% to its agricultural output value, reflecting its economic importance. The per capita availability of milk in Punjab is 1283 grams per day, highlighting the region's efficiency in dairy production. The livestock sector is pivotal, contributing 39% to Punjab's agricultural GDP (Statistical Abstract of Punjab, 2023). With only 1.3% of the total livestock population and 2.15% of the total bovine population of the country, Punjab 6.2% of total milk and 2.6% of total meat production in the country (BAHS, 2023). It provides employment and income stability to millions of rural households, emphasizing its role in poverty alleviation. The milk value chain is a comprehensive journey at national and state level that transforms raw milk into various consumer products, ensuring quality, safety, and efficiency. This article will delve into each stage of the milk value chain, highlighting its significance, challenges, and opportunities.

Dairy market in India:

India is ranked 8th in world for per capita fresh milk consumption over 5 times the world average driven mainly by large vegetarian population base in northern and western part of the country. However, the demand of milk and milk products is expected to grow by 5.5% whereas their supply is expected to increase by 5.7% in next 11 years leaving a gap of 37.6 million tonnes between demand and supply. As 52% is marketable surplus and 48% is retained by the farmers for household use, the supply projections should focus on marketable surplus available for consumers. If marketable surplus is adjusted by eliminating milk kept for home consumption, then demand will exceeds the supply in the country.

India’s dairy landscape has been dominated by AMUL (Anand Milk Union Limited), with a net turnover of around USD4.4 billion, for the last two decades. Amul Holds 27% of the market share, indicating it is a significant player followed by Nandini which Captures 9% of the market, mother dairy (5%), Hatsun (4%), Nestle (3%) and others account for the 52% of the market share

(Dairy in India Overview, 2020). This suggests that while Amul is a leading brand, there is a large portion of the market occupied by various other smaller players. Largest share of milk procured by cooperatives in India is by Gujarat having share of 45%, likely indicating a major cooperative or group, followed by Karnataka (20%) suggesting another significant cooperative, Maharashtra (8%), Tamil Nadu (7%), Rajasthan (5%) and others state cooperatives with 20% share.

Dairy Value Chain Components:

There are 6,49,481 (out of which 1.9% are in Punjab) having 641 districts (3.6% in Punjab). The Indian land is native to 139.34 crores of total human population in India (2,2% in Punjab) where 653.44 lakh (1.4% in Punjab) households own cattle and 391.8 lakh (3.8% in Punjab) households own buffalo (Various sources, 2023-24). The Domestic milk production is 36.6 Million L /day in the state out of which 52% is marketable surplus and 48% is retained by the farmers for household use (32% is used as fluid milk and 13% is kept for conversion). Apart from that, unorganized sector handles 56% of the marketable surplus and organized sector handles 44% of the surplus milk. According to Brar et al., 2017, home consumption in Punjab is 5.61 l/day (29%) and marketable surplus is 13.87 l/day (71%). The organized dairy structure in Punjab is composed of co-operatives and private milk plants processing 29% and 71% of the milk. There are 7,385 co-operative societies in Punjab. There are 11 milk processing plants in co-operative sector and 44 Chilling centres with capacity of 26.60 (lakh litres/day). There are 81 milk processing plants in private sector and 928 Chilling centres with capacity of 63.35 (lakh litres/day) (Statistical Abstract of Punjab, 2023).

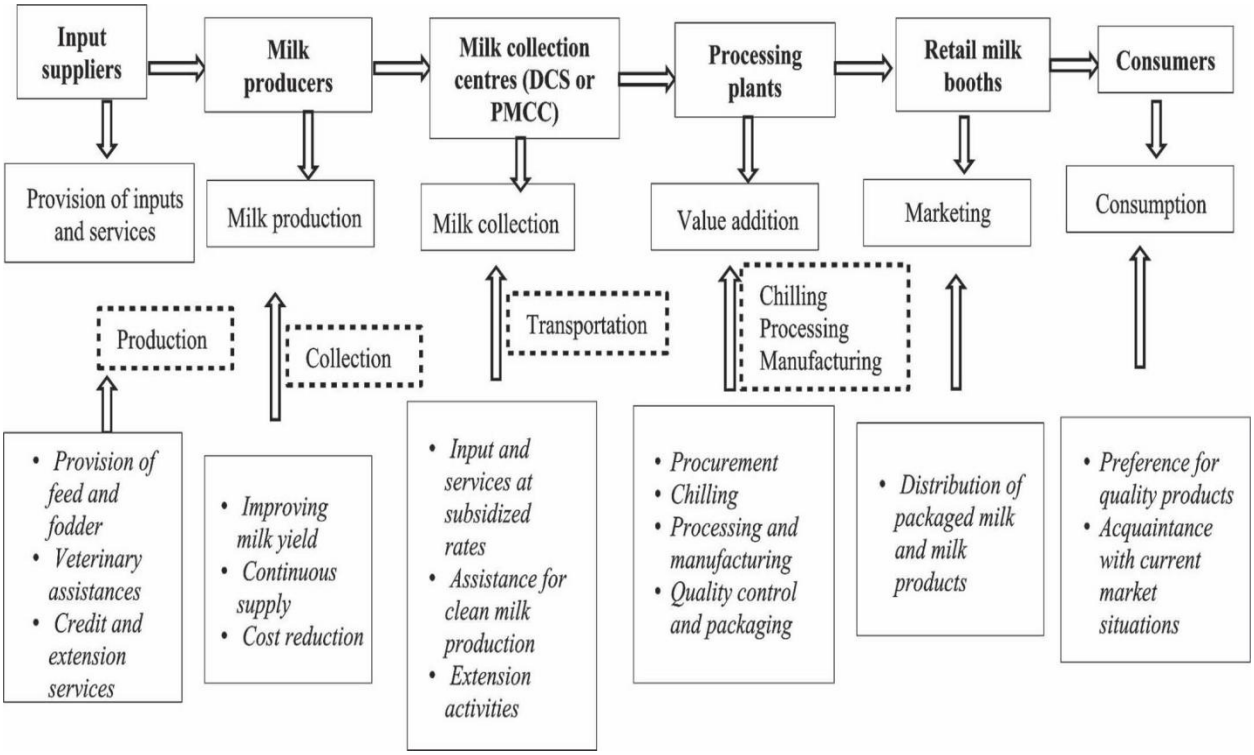

Fig. 1: Components of Dairy Value Chain in India (Mohapatra et al., 2022)

1. Production: This initial stage involves dairy farming and milk harvesting. Efficient farming practices and herd management are essential for maximizing yield and quality.

2. Procurement: Procurement involves the collection and initial handling of milk. It requires robust infrastructure and logistics to ensure timely and hygienic collection.

3. Transport: Transporting raw milk from farms to processing facilities is crucial. Maintaining cold chain logistics minimizes spoilage and ensures quality.

4. Processing & Packaging: This stage transforms raw milk into various products like cheese, butter, and yogurt. It involves pasteurization, homogenization, and packaging, demanding high standards of quality control.

5. Distribution: Processed milk products are distributed to retailers. Efficient distribution networks are vital to meet consumer demand promptly.

6. Retailing: Retailing involves the sale of milk products to consumers. It includes supermarkets, local stores, and direct sales channels.

7. Bulking and Cooling: Maintaining quality through proper storage and cooling facilities is essential to prevent spoilage and extend shelf life.

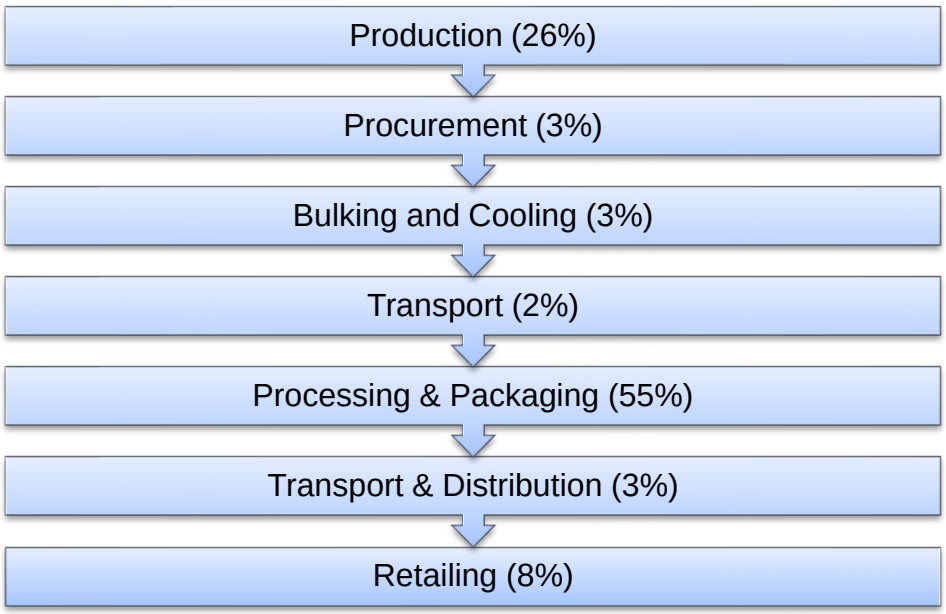

Fig. 2: Revenue Share in Dairy Value Chain

*Fig. 2 in parentheses indicate revenue share in value chain activities

It can be predicted from the Fig. 1 that maximum revenue is generated in the processing and packaging section with 55% of the total revenue from the entire dairy value chain followed by production (26%), retailing (8%) and procurement, bulking & cooling, transport & distribution each contributing to only 3% of the total revenue. Therefore, farmers should target practicing value addition at farm level in addition to processing & packaging which could alleviate their overall economic returns.

Various Marketing Channels Involved in Dairy Value Chain

There are two types of marketing channels prevalent in Punjab viz., organized and unorganized.

Organized Channels

- **Channel II**: Producer → Cooperative → Consumer
- **Channel III**: Producer → Private → Consumer

Unorganized Channels

- **Channel I:** Producer to Consumer
- **Channel IV:** Producer to Milk Vendors to Consumers
- **Channel V:** Producer to Milk Vendors to Sweet Shops to Consumers

These involve direct sales from producers to consumers or through local vendors, often bypassing formal processing facilities. As Shown in table 1, the farmers under Channel – II earns more profit than any other channel. So, Farmers under Cooperative system are earning more than any other system (Brar et al., 2017).

Table 1: Profit per litre of milk in various marketing Channels in Punjab (Rs./l/day)

Particulars	Channel II	Channel III	Channel IV	Channel V
Fixed Cost	2.77	2.81	2.76	2.91
Variable Cost	23.80	24.11	23.95	24.34
Total Cost	26.57	26.92	26.71	27.25
Milk Sale Price	30.27	29.50	30.22	30.00
Manure	0.47	0.51	0.43	0.39
Young Ones	0.26	0.28	0.28	0.28
Total Returns	31.00	30.29	30.93	30.67
Net Profit	4.43	3.38	4.22	3.41

Table 2: Marketing pattern of dairy milk products

	Lassi Plain		Paneer		Ghee		Khoya		Milk Cake		Pasteurized Flavored milk		Sterilized Flavored Milk		Dahi Plain	
Particular	**Amount (Rs./kg)**	**PCP (%)**	**Amount (Rs./kg)**	**PCP (%)**	**Amount (Rs./kg)**	**PCP (%)**	**Amount (Rs./kg)**	**PCP (%)**	**Amount (Rs./kg)**	**PCP (%)**	**Amount (Rs./kg)**	**PCP (%)**	**Amount (Rs./kg)**	**PCP (%)**	**Amount (Rs./kg)**	**PCP (%)**
Channel 1 (Producer - consumer)																
Producer price	**47.62**	**95.24**	**285.64**	**98.50**	**486.71**	**99.33**	**234.60**	**97.75**	**295.90**	**98.63**	**88.79**	**88.79**	**89.02**	**89.02**	**47.28**	**94.56**
Consumer price	**50.0**	**100.0**	**290.0**	**100.0**	**490.0**	**100.0**	**240.0**	**100.0**	300	100	100.0	100.0	100.0	100.0	50	100
Marketing efficiency	**20.65**		**65.56**		**147.97**		**43.48**		72.14		8.92		8.11		17.36	
Channel 2 (Producer – Retailer- consumer)																
Producer price	**48.04**	**80.07**	**287.37**	**89.80**	**487.42**	**97.48**	**235.74**	**90.67**	**295.51**	**84.43**	**76.28**	**76.28**	**76.52**	**76.52**	**46.70**	**77.83**
Consumer price	**60.0**	**100.0**	**320.0**	**100.0**	**500.0**	**100.0**	**260.0**	**100.0**	350	100	100.0	100.0	100.0	100.0	60.0	100.0
Price spread	**11.96**		**32.63**		**12.58**		**24.46**		54.49		23.72		23.48		13.3	
Marketing efficiency	**4.02**		**8.81**		**38.75**		**9.72**		5.42		3.79		3.26		3.5	

Producer Prices are generally higher in Channel 1 across all products due to direct sales whereas consumer Prices are higher in Channel 2 due to the retailer's involvement. Price Spread: Greater in Channel 2, reflecting the additional retail margin and Marketing Efficiency is Higher in Channel 1, indicating a more efficient direct market channel. Lower efficiency in Channel 2 is due to increased price spread and additional intermediaries.

Issues in Dairy Value Chain:

Issues that are prevalent in dairy value chain are as follows:

Milk Production at Farm: There is a limited access to high-yield breeds and modern farming techniques coupled with poor veterinary care, disease management and shortage of quality fodder & rising feed costs.

Milk Collection and Chilling: The state is facing inadequate collection centers and chilling facilities, lack of efficient logistics, leading to spoilage. There is difficulty in maintaining milk quality during transit.

Processing: There is insufficient processing capacity to handle peak supply and limited diversification into value-added products.

Packaging: there is lack of advanced packaging technologies and high costs affecting pricing competitiveness.

Marketing and Consumer Distribution: Farmers have limited reach to urban markets and export opportunities with volatile market prices affecting farmer income. There is a need for better branding and awareness campaigns.

Many small farms struggle with profitability due to high costs and limited market access. Increasing participation in the organized sector is essential to streamline operations and enhance productivity. Empowering cooperatives can enhance bargaining power and market reach for farmers. Adopting advanced marketing strategies and technologies can improve product visibility

and sales. The milk value chain is integral to the dairy industry, offering numerous benefits while facing distinct challenges. By addressing these challenges and capitalizing on opportunities, the sector can achieve sustainable growth and development, ultimately enhancing the livelihood of millions involved in dairy farming.

Fig 3: Issues in Dairy Value Chain

Conclusion and Policy Recommendations

Among the organised sector, producers share in consumer price is lowest which is the major bottleneck in diverting the milk from unorganised to organised sector. This share can be improved through strengthening the cooperatives including new generation cooperative (Producer's company) as price set by them becomes the bench mark for the milk market. Milk Prices Stabilization Fund is required to control the seasonal fluctuation of milk prices. Livestock Marketing Cell should be established for quality data generation and market intelligence for trading of live animals and marketing of milk & milk products. Non-plan Scheme for regular monitoring of cost of milk production in the state will be helpful for farmers and policy stake holders. Species wise milk collection should be popularized in the state as there is immense potential particularly for Buffalo milk and Goat milk. Punjab could distinguish and position itself

as pioneering and One Stop hub for buffalo milk products to harness its full potential as a dairy state. There is a need to focus on milk adulteration which I a cause of majority of the hurdles in development pace of the Punjab Dairy industry and also there is a need to establish milk quality control labs block wise. Sampling is primarily done by the Health Department in Punjab which needs to be shifted to Department of Animal Husbandry for more accurate data generation.

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Chapter 3

Beyond Conventional: The Game-Changing Role of Unconventional Feed Ingredients in the Value Chain

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India has the largest livestock population globally, with about 537 million animals (BAHS, 2023). In agriculture and allied activities, value chains have always been an existence in the sense that, farms carried out production and the final consumer accessed the produce, with the produce itself traversing through several channels and players. In this context, animal feed is the most pivotal input in livestock production system. But with only 2.4% of the world's surface area, India puts tremendous strain on its supplies of food, water, and land. Due to a severe lack of feed supply, animals in India are not able to produce at their maximum potential. Recent estimates indicate 11.24% deficit in green fodder, 23.4% shortage in dry fodder, and 29% deficit in concentrate availability (IGFRI, 2015). Generally dairy farmers use crop by-residues and locally available concentrate ingredients (oil cakes, bran, etc.) to feed their animals depending upon the productivity of the animals. This type of feed does not always provide protein, energy, minerals and vitamins required by the animal. Furthermore, it is quite unlikely that the area to produce green fodder would increase to its current extent in the next decades.

Given the rapid global economic growth and increased demand for animal-derived food products, it is essential to explore alternative feed resources. To achieve sustainable livestock development, it's important to use present feed resources efficiently, reduce waste and expand the resource base by seeking out innovative feed sources that do not compete with human food. Therefore, judiciously utilizing unconventional feed resources (UCFRs) for sustainable livestock production is the most viable approach to bridge the gap between supply and demand. In this

context, this chapter discusses about unconventional feed resources, their need, advantages, challenges, and various unconventional feed resources that can be used for feeding dairy animals.

What are unconventional feed resources?

Unconventional feed resources encompass feeds that deviate from traditional usage in animal feeding or are not typically part of commercially produced livestock rations. These resources include agro-industrial by-products, tropical browse plants, leaf meals, single-cell proteins and farm residues such as stubbles, haulms, straws and stovers. Their nutritive composition varies significantly and they may contain anti-nutritional factors, which could either benefit or potentially harm livestock. Exploring these alternative feed sources becomes crucial given the current limitations in India's feed resources.

Advantages of unconventional feed resources (UCFRs)

1. **Economic sustainability**: UCFRs offer economically viable substitutes for conventional feedstuffs. Using food industry waste and agricultural by-products, which are frequently accessible and reasonably priced, farmers can decrease their reliance on costly conventional feed while still providing their animals with proper nutrition.

2. **Environmental sustainability:** By lowering waste and carbon footprints, the use of UCFRs promotes environmental sustainability. It promotes a circular economy by diverting food waste and by-products away from landfills.

3. **Nutritious value**: Most of them are a great source of nutrients that support the activity of intestinal bacteria, which aids in the digestion of cellulosic biomasses. Nevertheless, some of them have low nutritional quality and large levels of undesirable elements, which hinder nutrient utilization and metabolic processes.

4. **Value addition and waste utilization:** By using UCFRs, it is possible to efficiently use by-products from farming and food processing that would otherwise be thrown away. Farmers may obtain more value from their crops by turning these resources into animal feed, which improves resource efficiency.

5. **Feed insurance:** UCFRs serve as an alternative source of feed during lean periods (e.g. tree foliage).

6. **Non-competitive with human consumption:** UCFRs do not compete directly with human food.

7. **Compatibility**: Most of the UCFRs fit well within existing farming practices.

(Andhale, 2024; Katoch et al., 2018)

Challenges and considerations related to feeding UCFRs

1. **Nutritional composition variability:** UCFRs can vary significantly in nutrient content and anti-nutritional factors. While they support intestinal microflora for digesting cellulosic biomass, some have low nutritive quality and high aversive factors that hinder nutrient utilization and metabolic processes. Ensuring a balanced and safe food for animals requires careful formulation and consistent examination.

2. **Process optimization:** To enhance digestibility and palatability, processing methods like drying, grinding and proper storage may be necessary for optimum utilization of UCFRs.

3. **Anti-nutritional factors:** Some UCFRs contain anti-nutritive elements such as toxins, enzyme inhibitors, or antimetabolites. Proper management and preventive measures are vital for better animal health and performance.

4. **Quality control:** To guarantee constant nutritional values and safety requirements for non-traditional feed resources, quality control procedures must be established. Routine certification, testing and monitoring procedures are required to maintain consistent nutritional values and safety standards for UCFRs.

5. **High collection costs**: Some feed resources, like rubber seeds, incur unusually high collection expenses.

6. **Processing challenges**: UCFRs processing can be difficult and problematic.

7. **Skills gap**: Lack of managerial and technical expertise hinders effective utilization.

8. **Market uncertainty**: Unclear marketability of end products poses challenges.

9. **Availability factors**: Time, location, seasonality, and storage affect UCFR utilization.

10. **Risk of aflatoxin toxicity**: Mould growth, such as aflatoxin in some of the UCFRs can be harmful. (Amata, 2015; Andhale, 2024)

Anti-nutritional factors in UCFRs

The presence of anti-nutritional factors in some UCFRs is a key barrier to their utilization. Anti-nutritional factors are chemical components found in feedstuffs that interfere with normal digestion, absorption, and metabolism. These factors can have deleterious effects on an animal's digestive system. For instance, tannins, saponins, oxalates etc. While they exist in both conventional and unconventional feeds, they are more common in the later (Pathak, 1997). To ensure safe use, procedures must be employed to remove or inactivate incriminating factors before incorporating these ingredients into animal diets.

Strategies for improving nutritional quality and digestibility of UCFRs: Various processing techniques that may be used to increase the nutritional content of UCFRs are discussed below:

1. **Chemical treatments**: Chemical treatments can enhance the nutritive value of UCFRs. Treating cereal crop residues with chemicals can improve their quality. Alkali pretreatment, particularly using ammonium hydroxide or calcium hydroxide, enhances nutritive value as it breaks down cell wall constituents, increasing crude protein content, feed intake and digestibility. Additionally, increasing non-protein nitrogen content with feed-grade urea has positive effects. Numerous research investigations have documented the beneficial impact of urea on the nutritional value of bagasse, straw, and residues (Elias and Fulpagare, 2015). Urea converts to ammonia via urease, impacting cell wall structure and ultimately increasing crude protein levels (Katoch et al., 2018).

2. **Ensiling agroindustrial by-products**: While various agroindustrial by-products exist, many remain underutilized in livestock feeding. For instance, tomato pulp, due to its high moisture content, is prone to becoming rancid and moldy. However, ensiling techniques offer a safe solution to extend storage periods for these by-products. Combining them with other materials like molasses or wheat bran further enhances their usability (Katoch et al., 2018).

3. **Feed block technology**: Utilizing agro-industrial byproducts with high moisture content becomes feasible through feed block technology. This approach optimizes the use of UCFRs, enhancing the economic viability of livestock production. Feed blocks consist of major components (feed sources) and minor components (micronutrients and additives). The flexibility of this method allows for the inclusion of inexpensive, readily available ingredients. By partially or fully replacing costly concentrate feeds with agro-industrial byproducts and tree leaves, feeding costs decrease. Additionally, feed blocks can deliver antihelminthic medications to control gastrointestinal parasites in browsing animals (Anindo et al., 1998).

4. **Biological treatment for enhancing feed value**: While chemical and physical treatments can improve the nutritive value of UCFRs, they often come with high costs and safety concerns. Alternatively, treating crop residues with microorganisms (such as fungi or bacteria) proves effective. Biological processing enhances feed value and digestibility without adverse effects on the environment or animal health. By disrupting the lignocellulose complex, biological treatments increase the accessibility of hydrolytic enzymes to cellulosic polysaccharides (Ramirez Bribiesca et al., 2010).

5. **Deactivation of secondary compounds:** To improve the nutritive value of UCFRs, various methods can be employed. Physically, chopping and grinding increase surface area, facilitating interactions between tannins and polyphenolic oxidases. Dilution of antinutrients occurs by combining tree leaves with other feeds and this reduces toxicity risks. Soaking or washing removes bitterness from saponins (Joshi et al., 1989). Storing chopped fresh leaves at 37°C accelerates the inactivation of total phenols and condensed tannins in feeds (Bhat et al., 2013). Simple heating or drying enhances protein quality. Chemical approaches include using polyethylene glycol-4000 (PEG-4000) to neutralize tannins.

In this chapter, few novel feedstuffs – Banana peels, apple pomace, potatoes, sugarbeet pulp, sugarcane tops, *Phalaris minor* seeds, guar meal, rice gluten meal, rice distillers dried grain with solubles (rice DDGS), waste bread, tomato pomace whose practical worth is relatively lesser-known have been discussed.

Banana peels: Banana peel accounts for around 30% of the weight of fresh bananas. Peels from ripe bananas can provide as much as 8% crude protein (CP), 6.2% ether extract (EE), 13.8% soluble sugars, and 4.8 total phenolics. Although the levels of Fe, Cu and Zn in banana peels are significantly greater than the maximum tolerance limit for ruminants, it is recommended that they be supplemented in the ruminant ration as a source of minerals rather than being fed *ad libitum*. Banana peels are rich in trace elements (Wadhwa and Bakshi, 2013). Hernan Botero et al. 2000 found that adding 15-30% banana peels to the diet of grass-fed Zebus resulted in considerable weight growth without any negative effects on health or palatability.

Apple pomace: Out of total global output, 30-40% of apples are damaged and hence not marketed, whereas 20-40% is processed for juice extraction. The residue remaining after juice extraction, known as apple pomace, might be utilized to feed cattle. The dried apple pomace has 7.7% crude protein and 5% ether extract. Adding up to 30% ensiled apple pomace to nursing Holstein cows' diet had no negative impact on milk output or composition (Wadhwa and Bakshi, 2013).

Potatoes: Fresh potatoes contain 65-75% starch, 9.5 percent CP, and 0.4 percent ether extract on a dry matter basis. Potatoes have minimal amounts of fibrous components such as neutral detergent fibre, acid detergent fibre, and cellulose. Potatoes have substantial levels of ME (3.16 Mcal/kg DM) and NE (1.87 Mcal/kg DM) for nursing dairy cows (NRC, 1989). Dairy and beef cows can be fed potatoes up to 15-20 kg/day. De Boever et al., (1983) found that raw potatoes had no negative impact on animal health.

Sugar beet pulp: Sugar beet pulp contains 10% crude protein and 1.1% EE, with 2.36 Mcal ME/kg DM and 1.38–1.47 Mcal NE/kg DM for nursing dairy cows (NRC, 2001). Fresh pulp can be fed to dairy cows and bullocks at rates of up to 12 and 24 kg/day. Dried beet pulp is suitable for feeding up to 3.5 kg/day to milking animals, 5.5 kg/day to fattening cattle, and 0.5 kg/day to 4-month-old calves (Wadhwa and Bakshi, 2013).

Sugarcane tops: Fresh cane tops have 3% CP and 45% TDN. They contain oxalate, which is an antinutrient. Sugarcane tops act as roughage in combination with concentrates. Sugarcane tops may be effectively ensiled both alone and with 0.5% urea. The silage is well tolerated by crossbred cattle and contains 47.8% TDN (Thakre et al., 2021).

***Phalaris minor* seeds:** *P. minor* (littleseed canary grass) belongs to Graminae family. It is commonly known as *Gulli danda*, *mandusi* and *gehun ka mama*. It germinates from November to January and matures in March-April. Favourable temperature for germination is 10-20°C. It has an erect stem with distinct nodes and internodes and at maturity the plants are taller than wheat. *P. minor* produces 300-450 seeds per panicle. There are 8-10 species of *Phalaris*, but these are so closely related that it is difficult to distinguish one from the other.

Kaur *et al.,* (2006) reported 83% *in vitro* organic matter digestibility in *Phalaris* seeds as compared with 92% for corn with the corresponding energy content of 8.9 and 9.5 MJ/kg, respectively. In addition, starch content of *Phalaris* seeds (50%) is comparable with that of barley (51%) but lower than corn (65%) and wheat (62%) (Kaur and Thakur, 2016). Furthermore, it was reported that *Phalaris minor* seeds could constitute 50% (w/w) of concentrate mixture for male buffaloes without inflicting their nutrient utilisation and health (Kaur et al. 2009). Regarding lactation performance, Kaur *et al.* (2017) concluded that *Phalaris* seeds can economically replace corn by 75% in concentrate mixture of Karan-Fries cows without any apparent adverse effect on intake, nutrient utilisation, milk yield, composition, liver enzymes and reproductive performance.

Guar meal: Guar or cluster bean (*Cyamopsis tetragonoloba*) is an annual drought tolerant leguminous crop of arid regions producing 5-12 hard seeds contained in a pod. India being the leading country in total guar seed production (>15 lakh tonnes) notably from the states of Rajasthan and Haryana, contributes to 80% of world guar trade. Major commercial utility of guar today is for its high viscous galactomannan gum (a natural hydrocolloid) which has various industrial applications. Guar meal is the principal by-product of guar gum production, which is made up of a mixture of guar germs (25%) and hulls (75%).

In India, guar meal is available mainly in two forms like guar meal churi (40-48% protein) and guar meal korma (50-55% protein), classified on the basis of protein content. Amino acid composition reveals that guar meal is one of the best protein sources as it is rich in lysine (1.72% DM) and sulfur containing amino acids (0.96% DM) at a concentration greater than that of GNC with comparable methionine content (Jongwe et al., 2014) and energy value (80% total digestible nutrients). The major constraint in its feeding is its bitter taste, which affects the palatability of feed. Incriminating factors like trypsin inhibitors, haemagglutinins, saponins and phytic acid, besides 18-20% of residual gum impedes its complete utilisation. Therefore, roasted/ toasted guar meal which is low in incrimination factors and less bitter in taste is employed in feeding monogastric animals. Nevertheless, guar meal supports optimum growth and lactation performance of dairy ruminants. A better growth rate and feed conversion ratio in growing crossbred calves fed guar meal replacing 50% groundnut cake (21% in concentrate) for a period

of 90 days was observed. However, at 75% inclusion, performance was reduced; nonetheless, upon supplementation of sweetener (Sucram®) and flavour (Lactovanilla®), respectively at 0.025% in the concentrate mixture, growth rate was improved (Goswami et al. 2012) without influencing any blood metabolites.

Similarly, Grewal et al., (2014) noted that guar by-products like guar *korma*, roasted guar *korma* and guar *churi* could safely replace 8% of soybean meal in the concentrate mixture of buffaloes. In a lactation study (Jongwe et al., 2014), it was evident that milk production was similar in Sahiwal cows receiving guar meal replacing 75% of GNC (21% in concentrate) in the concentrate mixture. Moreover, milk yield and composition as well as blood concentrations of glucose and urea nitrogen were not altered by dietary inclusion of guar meal. It is noteworthy to mention here that although cows generally do not relish the guar meal-based concentrate mixture initially, they get accustomed to its taste over a period of 15-20 days (Jongwe et al*.,* 2014).

Rice gluten meal (RGM): The RGM is the by-product obtained after wet-milling extraction of most of the starch from rice grain leaving behind brownish coloured protein-rich powdery material. It contains 47.5% CP and 3.1% ether extract. In a pioneering study conducted at ICAR-NDRI, Karnal, 50 and 75% of RGM was substituted isonitrogenously with groundnut cake (GNC) in the concentrate mixture of Karan Fries growing cattle. A 90-day feeding trial confirmed that RGM at both the levels did not exhibit any adverse effect on dry matter intake, digestibility of nutrients, nitrogen balance, growth performance as well as haematological variables. Regarding amino acid profile, RGM contained almost all essential and non-essential amino acids with slightly higher concentration (as % CP) methionine (2%) than GNC (1.2%). Based on the recommendations of this study that RGM could replace 75% nitrogen (N) of GNC, another study compared the by-products RGM and corn gluten meal (CGM) in growing Sahiwal cattle. On physical basis, the 3 concentrate mixtures used in this experiment contained GNC, RGM and CGM at 30, 22.7 and 17.5%, respectively. It was observed over a period of 3 months that nutrient intake and digestibility were similar across diets, while N balance and growth rate were greater ($P<0.05$) for calves receiving CGM-based diets than GNC, but comparable with that of RGM-based diet. Furthermore, there was no change in any of the blood metabolites such as glucose, total protein, plasma urea N and non-esterified fatty acids. In another study, Mahesh and

Thakur (2018) examined comparative nutritional potential of GNC, RGM and CGM by replacing 50% of GNC by RGM and CGM isonitrogenously in early lactating Murrah buffaloes for 120 days. No major changes were detected in terms of intake and digestibility; however, buffaloes fed CGM-based diet produced higher ($P<0.05$) milk yield than GNC, but comparable to RGM-based diet. Owing to relatively higher rumen resistant protein, CGM-based diets led to lower ($P<0.01$) milk and plasma urea N levels. Based on these trials, it was concluded that RGM can be incorporated in the concentrate mixture at 21-23% for growing cattle and 14% for lactating buffaloes.

Rice dried distillers' grains (Rice DDGS): The DDGS is a by-product of ethanol industry. Corn DDGS has been successfully used as an ingredient in dairy rations worldwide. However, recently, rice grains are also being utilized by the distilleries yielding rice DDGS (47% CP) as a potential by-product that is valued as a livestock feed. A study was conducted at NDRI on 18 lactating Murrah buffaloes in which the concentrate mixture containing 25% and 10% groundnut cake (GNC) and mustard cake (MC) were replaced at 50 and 75% levels on CP basis with rice DDGS. Milk yield, milk component yield (fat, protein, lactose and SNF) were higher in rice DDGS fed buffaloes. Overall mean milk urea and plasma urea values were lower in rice DDGS fed groups. Methane production was lower in 75% RDDGS fed group than the other two groups. Feed cost per kg 6% FCM production was lower in the rice DDGS fed buffaloes. Digestibility of nutrients, net energy balance, microbial protein synthesis and nitrogen balance was similar in all the three groups. It was concluded that rice DDGS can be utilized as an alternative protein source replacing 75% of GNC and MC in the concentrate mixture on CP basis of lactating buffaloes with improved milk production with added advantage in terms of reduction in methane emission and feed cost per unit milk production.

Chandrika et al., (2021) conducted a 90 day growth trial was conducted on 10-15 month old male buffalo (Murrah) calves (average initial body weight 252.92+17.0 kg. The animals in control group were fed with basal diet consisting of chopped wheat straw, berseem fodder and SBM based conventional concentrate mixture and animals in experimental groups 2 and 3 were fed wheat straw, berseem and concentrate mixtures in which SBM was replaced with DDGS at 50% and 75% levels on N basis, respectively. Digestibility of nutrients and nitrogen balance was

comparable in all the groups, indicating rice DDGS did not have any adverse effect on nutrient digestibility and nitrogen retention. Rice DDGS inclusion as a partial replacement of soybean meal had no deleterious effect on blood profile (total protein, cholesterol, triglycerides, BUN, glucose) and the values of all parameters were within the physiological range. It was concluded that rice DDGS can replace soybean meal upto 75 percent in the concentrate mixture of buffalo calves on N basis without any adverse effect on palatability, digestibility of nutrients, nitrogen balance and health of the animals.

Buffaloes calves offered rice DDGS based TMR

Waste bread: In bread manufacturing industry two types of wastes are produced, bread waste and waste bread. The bread waste is generated while manufacturing bread; it includes low quality products, default size or texture, burnt products, bread shreddings and dough waste etc. The bread waste is used as energy source in the ration of ruminants, swine and poultry and economizes the feeding cost. Cereal grains like wheat could be replaced completely by waste bread (WB) on nitrogen basis without any deleterious effect on the digestibility of nutrients, N-utilization, nutritive value or growth of animals. Moreover, keeping in view the cost of wheat (Rs 19-20/kg) and WB (Rs 7-9/kg), the feeding of animals could be economized through WB incorporated rations (Bhargava et al., 2022).

Tomato pomace: India is the second highest producer of tomatoes (19.76 million tonnes (mt)/ annum) after China (60.81 mt/annum) in the world. The leftover material after the extraction of pulp from tomatoes from tomato processing industry is called tomato pomace (TP). It is a

mixture of skin, core, seeds and residual pulp constituting 10-20% of processed tomatoes. But with the advancement in processing technology, TP constitutes only 2.0- 2.5% of processed tomatoes. Only 2.5% of fruits and vegetables produced in India are processed in the organized sector. In spite of very low quantity of fruit and vegetables being processed, approximately 1.81mt of fruit and vegetable wastes is generated. At present about $13x10^3$ tonnes TP is generated per annum in India. A large proportion of these wastes end up in landfills or rivers, causing environmental hazards. Pollution can be reduced considerably by recycling of these wastes through animal feed. However, the major constraints in using these wastes as livestock feed are their high moisture content. Bakshi et al., (2023) evaluated tomato pomace in the TMR of growing buffalo calves. Fresh tomato pomace was procured free of cost from Punjab Agro Juices Pvt Ltd, Hoshiarpur. It was spread on a concrete floor, sun dried and ground in a willey mill to pass through 1mm screen. The fractionation of proteins revealed that TP is a rich source of soluble proteins (albumin and globulins) as compared to insoluble fractions (prolamins and glutelins). Besides 2,2-diphenyl-1- picryl-hydrazyl-hydrate (DPPH) an antioxidant, it also contained other bio-active compounds like total phenolics, anthocyanins, saponins, vitamin C and flavonoids. TP is a rich source of carotenoids like lycopene and â-carotene. The tomato pomace replaced 50 and 100% of concentrate mixture. It was concluded that tomato pomace is a rich source of protein (21.50%), ether extract (11%) and bio-active compounds can replace concentrate mixture on N basis from 50-100% in the diet of growing buffalo calves.

Conclusion

Poor animal production often results from inadequate feeding due to a serious scarcity of feed resources. Unconventional feeds can help bridge the gap between nutrient requirements and availability. Farmers often lack awareness about integrating these feeds efficiently. Involving local extension organizations is crucial for dissemination of knowledge about the use of unconventional feeds. Furthermore, the use of unconventional feed resources should always be supported by research findings and professional advice since different livestock species and geographical conditions may require different considerations.

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Chapter 4

Goat to Great: Unlocking the Potential of Goat Farming's Value Chain

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In the intricate fabric of agriculture, goat farming stands out as one of the most resilient, versatile, and promising sectors. Across continents and cultures, goats have been indispensable companions to humanity, providing sustenance, economic stability, and cultural significance. Small ruminants make up approximately 41.57 per cent of India's total livestock population (20th Livestock Census, AH&D, 2019). The goat, often heralded as the "Sustainable Animal" of the Indian subcontinent, exhibits unique characteristics such as disease resistance, efficient feed conversion, and adaptability to diverse agroclimatic conditions, making it a vital asset in the nation's agricultural landscape (ICAR-CIRG, Annual Report, 2011). Furthermore, as climate change continues to challenge food security, the goats are expected to play a critical role in ensuring food security by 2050 (Sejian et al., 2019).

More than 76 per cent of goats are owned by marginal and small farmers, with less than 2 hectares of land (Singh et al., 2018). The country stands as the largest exporter of small ruminants' meat globally, exporting 8,695.97 MT valued at Rs. 447.58 crores (USD 60.04 million) in 2021-2022, with major markets including the UAE, Maldives, and Saudi Arabia (APEDA, 2021). The growing demand for meat has fueled the expansion of commercial goat farming across the nation. Yet, beneath their modest presence lies a complex value chain brimming with untapped potential. Exploring the multifaceted world of goat farming reveals pathways to transform it from a traditional practice into a dynamic and thriving enterprise. This transformation has the potential to uplift communities, ensure food security, and promote sustainable development. The goat value chain represents a critical segment of the livestock sector, encompassing various activities and resources necessary for the production, processing, and marketing of goats and their products. This chapter delves into the various components of the goat value chain in India, examining the flow of inputs and outputs, market dynamics, challenges, and opportunities for improving efficiency and sustainability.

Significance of goat farming

Goat farming holds a pivotal role in global agriculture, particularly in developing regions where it serves as a cornerstone for rural livelihoods. Goats are renowned for their adaptability, thriving in diverse environments from arid deserts to lush highlands. Their ability to convert marginal lands and poor-quality forage into valuable products makes them indispensable for smallholder farmers. Beyond meat and milk, goats provide fiber, hides, and even companionship, contributing to both economic and social well-being. According to the Food and Agriculture Organization (FAO), goats account for over a quarter of the world's livestock population, underscoring their global importance.

Understanding the goat farming value chain

To unlock the potential of goat farming, it is essential to dissect and understand its value chain, a sequence of interconnected activities that add value to goat products from inception to consumption. The value chain can be broadly divided into the following components:

- **Breeding and Genetics**: Focuses on selecting and propagating goats with desirable traits to enhance productivity, disease resistance, and adaptability. Combining traditional breeding with modern techniques like artificial insemination and genetic screening accelerates genetic improvement.

- **Nutrition and Feeding**: A balanced diet is crucial for goat productivity. Goats thrive on various forages, but optimizing their diet for specific goals (milk, meat, or fiber) involves high-protein feeds, mineral supplements, and innovative feed processing.

- **Health Management**: Effective health management includes disease prevention, timely treatment, and welfare. Regular vaccinations, parasite control, and access to veterinary care help maintain herd health.

- **Housing and Infrastructure**: Proper shelter protects goats from weather and predators while improving management efficiency. Adequate infrastructure (fencing, water systems, storage) supports sustainable farming.

- **Production and Processing**: Involves managing goats for optimal growth, reproduction, and health. Processing transforms raw products (milk, meat, hides) into market-ready goods, adding value and extending shelf life.

- **Marketing and Distribution**: Connects products with consumers through effective strategies, understanding market demands, and building strong brands. Digital platforms and e-commerce expand market access.

- **Retail and Consumption**: Ensures products meet quality and safety standards for consumer satisfaction. Retailers bridge the gap between producers and consumers, promoting goat products and driving demand.

Input Value Chain

The inputs of the goats' value chain encompass resources like breeding stock, feed, healthcare, housing, information, essential for producing quality animal products, enhancing market access, and improving farmer livelihoods. Quality breeding stock, selected based on genetic traits, ensures healthy and productive goats. Adequate feed and nutrition are critical for maintaining health and productivity, while veterinary healthcare services address disease prevention and control. Housing and equipment provide shelter and infrastructure, and capacity-building initiatives through training help farmers adopt best practices for goat management.

The dominance of indigenous goat breeds like Beetal, Barbari, Jamnapari, and Sojat among livestock keepers stems from their remarkable adaptability to local environmental conditions, inherent disease resistance, and lower maintenance costs. These native breeds thrive in diverse agro-climatic zones, requiring minimal inputs, which makes them an economically viable and sustainable choice for the rural farmers. Farmers commonly purchase new animals from various sources like fellow farmers and traders, favoring traders for their convenience in doorstep delivery. The resource-poor farmers predominantly rely on grazing as the primary source of feed for their animals, while a smaller group combines grazing with stall feeding. Feeding tree leaves, such as Kikar/Babul (Acacia nilotica), Drek (Persian lilac), Neem (Azadirachta indica), Jamun (Syzygium cumini), and Ber (Ziziphus mauritiana), is also practiced by some of the farmers. Hay feeding is widely practiced by farmers, particularly during the winter months. However, the use of commercial or readymade concentrates for small ruminants is either not practiced at all or adopted by only a few. A significant portion of farmers rely on self-medication using modern veterinary drugs based on their own experience, while only a few of them seek assistance from a licensed veterinarian for treatment. The rural farmers prefer ethnoveterinary practices to treat their animals due to their greater accessibility compared to modern veterinary medicines (Fig. 1).

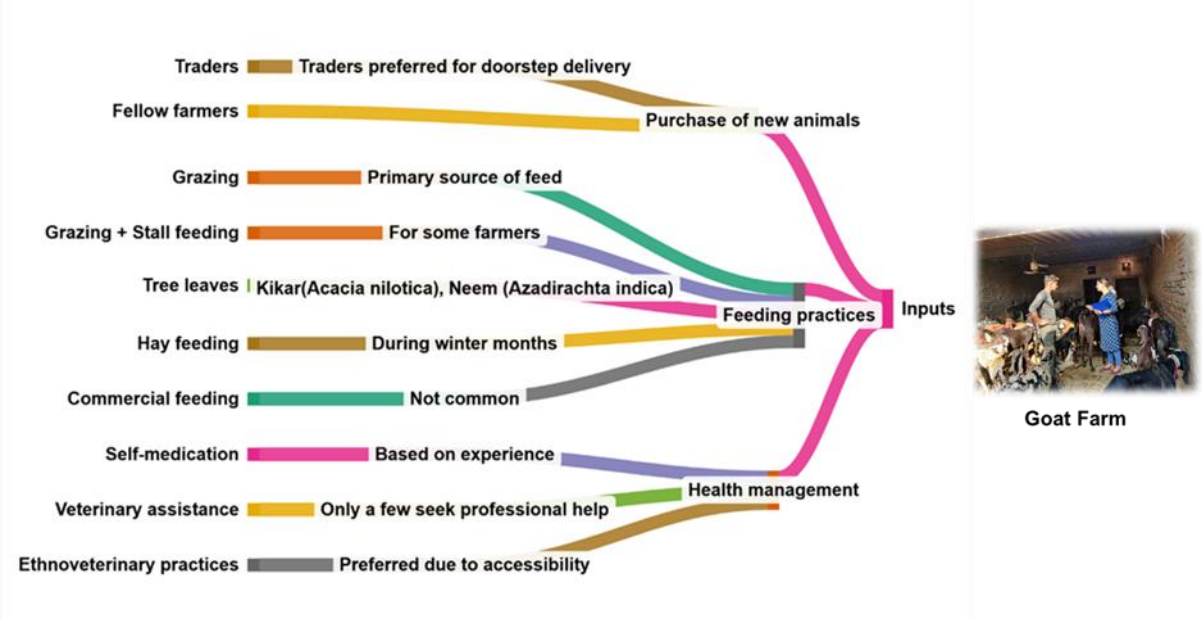

Fig. 1 Representation of input value chain derived from interviews with 385 goat farmers and 20 key informants (Chadda et al., 2024a)

Output value chain*:* Outputs from the goat value chain feature core products such as milk, meat, fiber, and hides, along with services like processing, which enhance the livelihoods of farmers and other stakeholders. Variants of output value chain are described below.

Meat

India's goat meat sector has witnessed significant growth in production and consumption, driven by rising demand for both fresh and processed products. While fresh meat remains the dominant product, the processed segment is expanding at a rate of 15-20% annually, supported by e-commerce platforms and startups like Licious, TenderCuts, and Zappfresh (Gadekar et al., 2023). The demand for mutton is especially high in southern states, and digital platforms are anticipated to grow further as consumer awareness increases.

Despite its growth, the goat meat sector remains largely unorganized, with only 4% of meat processed and sold in markets. This inefficiency, coupled with numerous intermediaries, leads to seasonal price fluctuations and inflated costs by 25-30%. To remain competitive on the global stage, India must enhance the quality of its goat meat to align with international standards.

Modern integrated processing facilities are being established to optimize the use of byproducts while ensuring compliance with these standards. Additionally, initiatives to promote organic goat meat, including certification and branding, are crucial to tap into the burgeoning organic market.

Milk

Goat milk offers several unique advantages, including high digestibility, therapeutic properties, and health benefits due to its unique composition. It contains smaller fat globules, which enhance digestion, and medium-chain fatty acids with antibacterial, antiviral, and anti-cholesterol properties. Rich in oligosaccharides, it promotes gut health and has prebiotic, anti-infective, and anti-inflammatory properties. However, the processing of goat milk in India is minimal, and the sector remains underdeveloped. Promoting value addition, establishing a robust network of village-level cooperative societies, and raising consumer awareness about the nutritional and medicinal benefits of goat milk could invigorate the sector. This would meet growing consumer demand for functional foods while supporting farmers and fostering sustainable growth.

Manure

Goat manure, rich in nitrogen, phosphorus, and potassium, significantly improves soil fertility, particularly in horticulture and floriculture. Traditional practices like "goats penning" enhance soil fertility by allowing flocks to graze on fields post-harvest, enriching the soil with nutrients. Waste wool from sheep also has potential as an organic soil amendment, enhancing soil quality and water retention. Despite its biodegradable nature, it poses environmental hazards due to airborne fine particles, but its use as manure can improve soil fertility, crop yield, and water use efficiency.

Skin and hide

The goat skin and hide value chain in India has significant potential but is currently hampered by inefficiencies in processing, outdated tanning methods, and inadequate infrastructure. Only a small percentage of goat skins are considered high-grade due to these

challenges. The adoption of standardized quality control and eco-friendly practices, along with modern processing facilities, is crucial for enhancing market competitiveness and meeting global standards. Improving this value chain can provide substantial socioeconomic benefits, including job creation and improved livelihoods, emphasizing the need for better processing and marketing strategies.

Goat market structure and dynamics

The goat value chain involves various actors, including producers (smallholder farmers), collectors, livestock marketing cooperatives, traders, butchers, hotels, supermarkets, consumers, and export abattoirs. In India, goats are ideally sold at 7 to 9 months old, weighing between 24 to 26 kg. However, in regions like Maharashtra, limited grazing resources, high risk of mortality, loss of milk income, and immediate household income needs compel many farmers to sell male kids at 3.0 to 3.5 months old (Shinde and Mahanta, 2020). In Rajasthan and Uttar Pradesh, only 22% and 26% of farmers, respectively, sell male goats over one year old (Kumar et al., 2009). Rearing male kids for breeding is rare, with only a few selected based on physical traits and breed characteristics to fetch higher market prices.

Goats are sold in three primary market types in India (Devendra, 2015):

- **Assembling markets:** Animals from nearby villages are collected and bought by middlemen, butchers, and traders.

- **Distribution markets:** Located in peri-urban areas near abattoirs, where traders bring goats from assembling markets to sell to butchers and wholesale meat dealers.

- **Weekly markets:** Controlled by municipalities, held on specific days in big cities and peri-urban areas, where prices are negotiated between traders and farmers.

Farmers often prefer selling goats in rural areas to avoid long-distance transport, which can cause significant weight loss and reduce market value. For instance, transporting goats over a distance of 150 km can lead to a weight loss of 0.95-3.18% depending on the season (Vignesh et

al., 2018). Innovative marketing approaches, such as youth-led direct marketing to urban markets, have demonstrated potential benefits, yielding 25-30% higher prices (Hegde and Deo, 2015).

Marketing channels and price determinants

Several marketing channels exist for goats, ranging from direct sales to intermediaries' involvement. A study in Karnataka found that farmers received only 82% of the market price, with returns declining as the number of intermediaries increased (Shivkumara et al., 2017). Factors influencing goat sale prices include body weight, breed, sex, number of buyers, festivals, and seasons. Bashir and Venkatachalapathy (2017) identified five goat marketing channels (Fig. 2), highlighting varying profit distribution among farmers, traders, butchers, and commission agents.

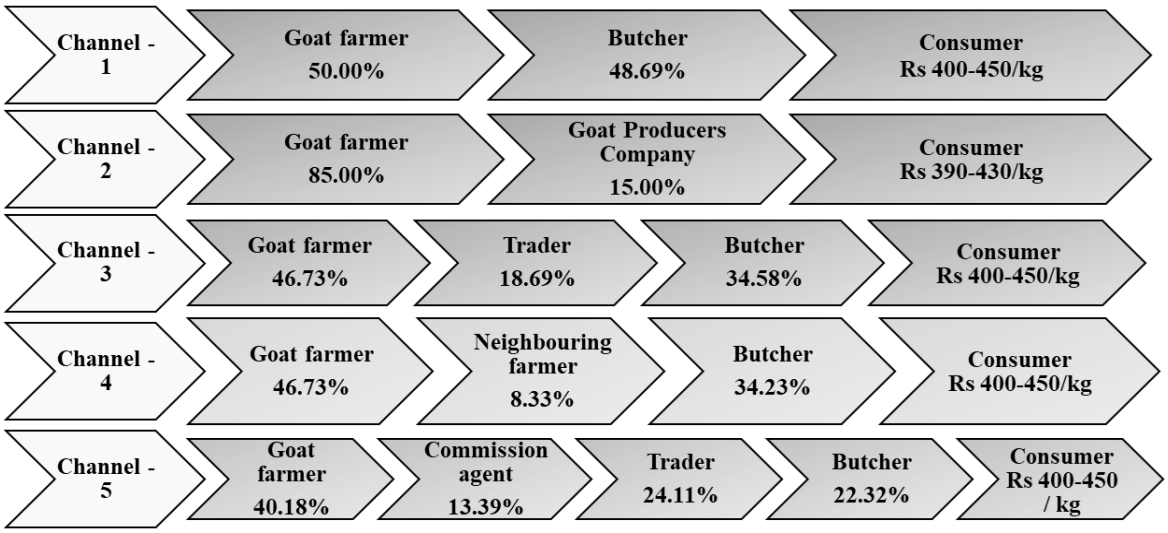

Fig. 2 Various channels for marketing of goat (Source: Bashir and Venkatachalapathy, 2017)

The goat markets are predominantly controlled by a long chain of intermediaries, limiting new entrants, and reducing farmers' bargaining power (Gupta and Suresh, 2010). To enhance goat marketing, it is vital to develop structured pricing formulas based on live weight, breed, age, body condition, and sex. Introducing modern weighing systems, transparent auction displays,

and veterinary check-ups at markets will ensure fair pricing and healthier animals. Strengthening institutional mechanisms, modernizing markets, and enhancing farmer, butcher, and trader capacity can further improve the goat marketing system.

Digital marketing and the future of goat sales

Digital marketing is revolutionizing goat sales, expanding the market reach and improving transaction efficiency. Online platforms and social media have enabled farmers and traders to tap into global markets, enhancing visibility and accessibility. Sharma et al. (2021) reported that digital marketing strategies have significantly expanded market reach and improved transaction efficiency. As digital tools continue to evolve, their role in goat marketing is expected to become increasingly pivotal, transforming traditional practices and driving industry growth.

India lacks a dedicated market for goat milk, and hence it is commonly blended with cow milk for sale. Value addition of milk is entirely absent among rural farmers, with only an exceptionally small number engaging in such practices. The key players in animal sales include traders, fellow farmers, and butchers. Traders or middlemen dominate goat marketing, purchasing most animals from smallholders and playing a pivotal role in the trade. Traders sell live goats to butchers or processors, who then slaughter them to add value. In return, traders receive a significant commission from the butchers, who are not directly linked to the farmers. To ensure consumer safety, butchers must comply with strict food safety standards. However, they often purchase live animals from farmers, traders, and goat markets without obtaining health certificates. None of them ever condemn meat or report suspected sick animals to the authorities. Surprisingly, some sell the dead animals to butchers. This practice leads to health risks, including the spread of diseases, poor meat quality, and consumer safety concerns, as the animals are not properly inspected before slaughter. Farmers often dispose off animal carcasses and placental waste in open areas, grazing fields, or water sources, unaware of the environmental and health dangers it poses. This improper disposal can attract predators and scavengers, creating serious health risks for both humans and livestock (Fig. 3).

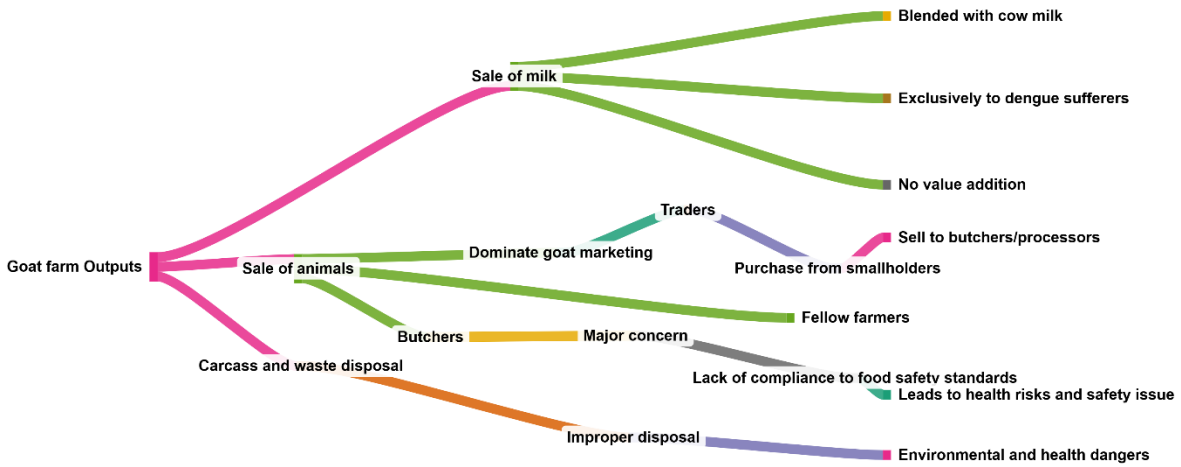

Fig. 3 Representation of output value chain derived from interviews with 385 goat farmers and 20 key informants (Chadda et al., 2024a)

Challenges and opportunities in the goat value chain

Goat farmers in rural areas face numerous challenges, including financial instability due to limited access to credit, subsidies, and insurance. High feed costs, unorganized marketing, inadequate slaughter facilities, low dressing yield of local breeds, and cases of theft further complicate their situation (Chadda et al., 2024b). Beyond the market challenges in goat trading, the improper disposal of dead animals at knacker yards poses significant public health risks and highlights a lack of safety awareness in the industry (Singh et al., 2020). Enhancing the capacity of goat farmers through training in scientific rearing techniques and modern production methods presents a valuable opportunity to ensure healthier livestock and improve overall productivity (Meena et al., 2022). Implementing safety protocols and improving access to healthcare are essential to address hazards such as toxic gas emissions, pesticide exposure, zoonotic diseases, and unsafe handling practices (Chadda et al., 2024c). Despite these challenges, there is hope for a brighter future through the formation of cooperative societies, the use of aggregators for pooling, grading, weighing, and transporting goats, and the modernization of markets and infrastructure. Government-supported initiatives, such as providing modern infrastructure near production units, transparent auction displays, and veterinary check-ups, can significantly improve market efficiency and profitability for goat farmers.

Conclusion

The goat value chain in India presents a complex web of interactions among various stakeholders, from producers to consumers. A comprehensive approach that includes promoting value addition, establishing robust networks of cooperative societies, adopting eco-friendly practices, and raising consumer awareness can invigorate this sector. By leveraging India's vast genetic diversity, production capabilities, and adopting innovative marketing and processing strategies, the livestock value chain can significantly enhance productivity, profitability, and sustainability. This, in turn, can support the livelihoods of smallholder farmers, foster economic growth, and meet the increasing demand for high-quality dairy and meat products, functional foods, and sustainable agricultural inputs, thereby creating a thriving ecosystem for the small ruminant farming industry.

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Chapter 5

Integrated Farming Systems: The Future of Sustainable Agriculture

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In India, about 85 percent farmer community comes under the marginal and small farmers' category (GOI, 2018). In the face of growing environmental concerns and the need for sustainable agricultural practices, Integrated Farming Systems (IFS) have emerged as a viable solution. IFS combine various agricultural activities such as crop production, livestock rearing, aquaculture, and agroforestry into a cohesive unit. This holistic approach not only enhances productivity but also promotes environmental sustainability. With the increasing pressure on agricultural systems to produce more with less, IFS offers a promising path forward for farmers worldwide.

What is Integrated Farming System?

Integrated Farming Systems (IFS) are designed to optimize the use of resources through the integration of different agricultural activities. The concept revolves around creating a synergistic environment where the waste from one component becomes the input for another. For example, crop residues can be used as feed for livestock, and livestock manure can be utilized as fertilizer for crops. This interconnectedness reduces waste and enhances resource efficiency. Historically, traditional farming practices often incorporated elements of integration, but modern IFS have refined and formalized these practices to maximize their benefits. Thus, IFS is a reliable way of obtaining high productivity with substantial nutrient economy in combination with maximum compatibility and replenishment of organic matter by way of effective recycling of organic residues/wastes etc. obtained through integration of various land- based enterprises (Gill et al., 2010; Solaiappan et al., 2007).

Principles of Integrated Farming Systems

1. *Diversification:* Combine various agricultural activities like crops, livestock, aquaculture, and agroforestry to reduce dependency on a single type of production and enhance resilience.

2. *Resource Recycling:* Utilize waste products from one component as inputs for another (e.g., crop residues as livestock feed, manure as fertilizer) to minimize waste and external inputs.

3. *Synergy and Complementarity:* Design systems where different components support each other, maximizing positive interactions (e.g., integrating fish farming with rice paddies).

4. *Sustainability:* Focus on long-term environmental health by maintaining soil fertility, conserving water, and promoting biodiversity to ensure future farm viability.

5. *Efficiency:* Optimize the use of resources like land, water, labor, and capital to increase productivity while reducing costs and labor inputs.

6. *Resilience:* Enhance the farm's ability to withstand and recover from adverse conditions such as extreme weather, pests, and diseases by diversifying income sources and practices.

7. *Adaptability:* Implement flexible practices that can be adjusted based on changing environmental conditions, market demands, and technological advancements, encouraging continuous learning and innovation.

8. *Integration of Modern Technology:* Use modern agricultural technologies like precision farming and smart irrigation systems to enhance productivity and sustainability, combining traditional knowledge with modern practices.

9. *Community Engagement:* Foster collaboration and knowledge sharing among farmers, researchers, and policymakers, promoting community-based initiatives and support networks.

10. *Economic Viability:* Ensure the system is economically sustainable by providing multiple income streams and improving market access, focusing on cost-effectiveness and profitability to support farmers' livelihoods.

Benefits of Integrated Farming Systems

Environmental Benefits

- Improve soil health through natural fertilization with animal manure
- Reduce the need for chemical fertilizers and pesticides
- Promote biodiversity by integrating various plant and animal species
- Conserve water through recycling within the system
- Minimize pollution from agricultural runoff

Economic Benefits

- Lower production costs by recycling resources (e.g., crop residues as livestock feed, manure as fertilizer)
- Diversify income sources, reducing vulnerability to market fluctuations and climate uncertainties
- Provide multiple revenue streams from crops, livestock, and aquaculture

- Enable continuous income generation throughout the year
- Open new market opportunities with diverse products

Social Benefits

- Enhance food security by producing a variety of nutritious foods
- Create employment opportunities, supporting rural economies
- Promote community development through job creation and economic growth
- Encourage knowledge sharing and collaboration among farmers
- Empower farmers with training and education on sustainable practices

Successful IFS model under Indo-Gangetic plains (PAU, Ludhiana)

The research was carried out at the School of Organic Farming, Punjab Agricultural University, Ludhiana, as part of the "All India Coordinated Research Project on Integrated Farming Systems (ICAR)" from 2018-19 to 2021-22. The Integrated Farming System model experiment began during Kharif 2010. The study involved a 1.0 ha model (10,000 sq m area) incorporating crops, horticulture, aquaculture, dairy, goatry and agroforestry components. During the Kharif season, 6400 sq m was dedicated to growing paddy, maize, and turmeric. In the subsequent rabi and summer seasons, potato, berseem, wheat, gobhi sarson, onion, pearl millet, and spring maize were cultivated. Additionally, 1600 sq m was used for horticulture with guava and citrus plantations, and the 1500 sq m inter-row space was used for raising vegetable crops. The remaining areas included 200 sq m for dairy (2 cows, 1 buffalo, and 9+1 goats), 1000 sq m for aquaculture, and 300 sq m for agroforestry. Boundary plantations with craneberry (Karonda) and galgal were also established. The results indicated that adopting an integrated farming system, which included crop-based enterprises, horticulture, dairy, and aquaculture, yielded an average net return of Rs 5,58,253. Dairy contributed the highest net return of Rs 3,17,286,

followed by crops (Rs 1,27,559), horticulture (Rs 29,129), aquaculture (Rs 26,648), boundary plantation (Rs 21,785), goatry (Rs 20,257), agroforestry (Rs 17,062), and kitchen gardening (Rs 8,047). Overall, the 1.0 ha model for marginal and small farmers generated gross returns of Rs 9,27,888/ha, with costs of Rs 3,69,635/ha, resulting in net returns of Rs 5,58,253/ha, significantly higher than the traditional rice-wheat system which yielded Rs 1,35,989/ha.

Table 1: Relative efficacy of different farm enterprises in the integrated farming system model at PAU, Ludhiana

Farm Enterprises	Size of the unit (area/number)	Gross returns (Rs)	Cost of cultivation (Rs)	Net returns (Rs)
Field Crops (Cereals/pulses/oilseeds/ green fodders etc.)	6400 m^2	208072	80513	127559
Horticulture (Guava, Lemon, vegetable intercrops)	1900 m^2	59629	30500	29129
Agro-forestry Poplar with Turmeric-Wheat	300 m^2	20257	3195	17062
Dairy (Cows + Buffalo)	200 m^2	546444	229158	317286
Goatry	9+1	39604	19347	20257
Aquaculture (Fresh water fish production)	1000 m^2	31408	4940	26468
	High density guava plantation			
Boundary plantation	-	28165	6380	21785
Kitchen gardening	200 m^2	12627	4580	8047
Total allocated land	10000 m^2	**927888**	**369635**	**558253**
Rice-Wheat	10000 m^2	224726	88737	135989

Conclusion

Integrated Farming Systems offer a sustainable solution to many of the challenges facing modern agriculture. By enhancing productivity, promoting environmental sustainability, and providing economic and social benefits, IFS represent a forward-thinking approach to farming. The adoption and support of IFS will be crucial in ensuring a resilient and sustainable agricultural sector. Policymakers, researchers, and farmers must work together to promote and implement IFS practices on a larger scale. Through collective effort, can achieve a more sustainable and prosperous future for agriculture.

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Chapter 6

FPO: Linking Hands, A Collective Power In Fortifying Value Chains

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Most rural impoverished people in the globe, as well as a sizeable fraction of urban impoverished people, own livestock and use it for a range of purposes that go well beyond income generation (Randolph et al., 2007). In rural India, agriculture and allied sectors (such as livestock farming, fisheries, aquaculture etc.) constitute a major source of livelihood and play a crucial role in Indian economy. These sectors are now growing exponentially and contributing to better farm incomes. The livestock sector grew at a Compound annual growth rate (CAGR) of 7.9 per cent during 2014-15 to 2020-21, and its contribution to total agriculture GVA has increased from 24.3 per cent in 2014-15 to 30.1 per cent in 2020-21 (Economic survey, 2022-2023).

There is a dynamic market of livestock and livestock products at global level due to increase in purchasing power and other factors. However, the vast bulk of these markets are domestic, do not cross international boundaries and are driven by local demand. Managing these supply chains requires addressing the complexity of handling and regulating highly perishable products, which at times also present greater human health implications than crop products (Staal, 2015).

Major population (nearly 86% of the farmers) of Indian farmers are small (1.00-2.00 hectare operational land holding) and marginal farmers (Below 1.00 hectare operational land holding). Thus, such a small holding make livelihood very difficult. Also, a large chunk of population is directly or indirectly linked with livestock sector. At rural level, almost every

household has 2-3 livestock. Livestock products (milk, meat and other value added products) are equally relished by urban and rural people. The livestock sector contributes significantly in spawning employment opportunities and supplementing the income of small and marginal farmers.

Challenges faced by small farm holders in Agriculture and Livestock sector:

1. Drought, climate change, monsoon failure
2. Crop failure
3. Lack of proper irrigation facilities
4. High cost of input (if purchased in small quantities):- Machinery and livestock equipment's are out of reach of small and marginal farmers mainly because of higher prices.
5. Perishable nature of livestock produce
6. Forced sale of produce (low in quantity) to middlemen. Farmers are forced to sell their farm produce, which is disposed of at a very cheap price, to local dealers and middlemen in the absence of reliable marketing services.
7. Lack of knowledge of market and poor marketing skills
8. Inadequate human resource,
9. Lack of resources such as storage conditions
10. Less credit available:- Scarcity of capital for agricultural and other allied activity forces by which farmers need to borrow money for improving the production.

11. Lack of extension services

12. Low level of technology adoption

13. Low income due to poor infrastructure

FPO – a ray of hope for current problems of farmers

One of the main projects of the Indian government is the Farmer Producer Organization (FPO), which links farmers to the market, gives them a business perspective on farming, and assists them in organizing into groups in order to raise their socioeconomic status. A Farmer Producer Organization (FPO) is a collective of farmers who come together to pool their resources and collectively market their produce. FPOs empower smallholder farmers by enabling them to access better inputs, technology, credit, and markets, thereby enhancing their bargaining power and income.

- The idea behind Farmer Producer Organizations (FPOs) is that farmers, who produce goods for the agricultural and other allied sectors, will form groups and register under the Indian Companies Act or Cooperative society act. So, FPO is a registered body.

- The goal is to make farmers more competitive and give them an advantage in emerging markets by creating effective and crucial role in value chain.

- The FPOs' main functions will be to supply seed, fertilizer, and machinery; link farmers to markets; provide training and networking opportunities; and offer financial and technical advice.

- Profit Sharing: To ensure that the organization's benefits are shared equitably, FPOs divide a portion of its profits among its members.

- Ownership: The ownership of the FPO is with its members, who are considered as primary producers.

- Support: FPOs receive support from various institutions and agencies, including NABARD, SFAC, and government departments, for their promotion

Role of FPO in value chain of livestock produce

Value chain analysis is a strategic tool used to understand the series of activities that are performed to deliver a valuable product or service to the market. It involves analyzing each step in the production and distribution process to identify opportunities for efficiency improvements, cost reduction, and value addition. The entire range of tasks involving various individuals needed to move a product—such as a live animal, meat, milk, egg, day-old chick, feed, medicine, leather, fiber, and manure—through the various stages of production, processing, and delivery to final consumers is known as the livestock value chain.

When these concepts are combined, FPOs can use value chain analysis to identify where value is created, captured, or lost along the entire supply chain of their agricultural products. By understanding the value chain, FPOs can make informed decisions about which activities to prioritize for intervention, such as improving production techniques, optimizing transportation and logistics, or investing in processing facilities. This can help FPOs to increase the overall value of their products, improve market competitiveness, and ultimately enhance the livelihoods of their member farmers.

FPOs play a crucial role in the value chain of livestock produce by facilitating coordination and collaboration among smallholder farmers and other stakeholders involved in the production, processing, and marketing of livestock products. Following are the some of the key roles that FPOs can play:

a) **Aggregation and Collective Bargaining:** FPOs enable smallholder livestock farmers to aggregate their produce, which helps in achieving economies of scale. By collectively bargaining with buyers, processors, and input suppliers, FPOs can negotiate better prices for inputs and fairer prices for their products, enhancing the income of member farmers. FPO also reduces dependency on middlemen.

b) Cost Efficiency: Through shared resources such as equipment, storage facilities, transportation, and packaging, FPOs reduce costs per farmer. This improves profitability and competitiveness in the market.

c) Access to Inputs and Services: FPOs can facilitate access to quality inputs such as animal feed, veterinary services, and healthcare products at discounted rates through bulk procurement. This improves the productivity and health of livestock, leading to higher-quality produce. By pooling resources and produce, FPOs can access larger markets that individual farmers may not reach. This includes accessing organized retail chains, export markets, and government procurement programs.

d) Capacity Building and Training: FPOs provide training and extension services to member farmers on best practices in livestock management, including animal husbandry, disease control, and nutrition. This enhances the technical skills and knowledge of farmers, leading to improved productivity and product quality.

e) Combining of produce: The FPO may also combine the produce from all of its members and sell it in bulk for a higher price per unit (Rashtrapal et al., 2022).

f) Quality Assurance: FPOs often implement quality control measures and certifications, ensuring that produce meet market standards. This enhances the marketability of their products and opens up premium markets.

g) Technology Adoption: Adopting appropriate technologies can improve productivity, reduce costs, and enhance product quality. FPOs may introduce members to new farming technologies, irrigation methods, digital platforms for market information, and farm management tools.

h) Market Linkages: FPOs play a vital role in connecting smallholder farmers with formal markets, processors, retailers, and exporters. By establishing direct linkages with buyers and negotiating contracts, FPOs help access of farmers to higher-value markets and ensure a fair share of the value created in the supply chain.

i) **Quality Control and Certification:** FPOs can implement quality control measures and certification schemes to ensure that livestock products meet the required standards and certifications, such as organic or fair trade certifications. This enhances the marketability of products and enables farmers to command premium prices.

j) **Value Addition and Processing:** FPOs may invest in value addition activities such as processing, packaging, and branding of livestock products. By adding value to raw produce, FPOs can capture a larger share of the value chain and create diversified income streams for member farmers.

k) **Economies of Scale:** FPOs can increase their members' income by negotiating better pricing with suppliers and bulk customers by pooling their produce.

l) **Insurance:** FPO provides various insurances to its member such as life insurance, crop insurance etc. (Khan et al., 2020).

m) **Policy Advocacy and Representation:** FPOs advocate for the interests of smallholder livestock farmers at the policy level, lobbying for supportive policies, regulations, and infrastructure investments that enhance the competitiveness of the livestock sector and improve the welfare of farmers.

n) **Risk Mitigation**: By diversifying production and pooling resources, FPOs can better manage risks related to market volatility, climate variability, and production uncertainties.

o) **Social Impact**: FPOs strengthen social cohesion among farmers, particularly marginalized groups, by promoting inclusive growth and addressing socio-economic disparities.

p) **Social and Environmental Sustainability:** FPOs promote sustainable farming practices that conserve natural resources, mitigate climate change impacts, and ensure social

equity. They may encourage organic farming, promote biodiversity conservation, and implement fair labour practices.

Emerging role of FPOs in marketing of livestock produce

- Livestock goods are particularly perishable and come from highly dispersed production systems that are positioned far from consumer markets.

- To realize their higher worth, they thus need more effective marketing and processing systems throughout their whole value chain, from manufacturing to consumption.

- Since the majority of livestock farmers in India are small-scale, resource-poor, and frequently unable to forge their own connections with markets, processors, and customers, marketing and processing operations are even more important.

- With a few notable exceptions, the marketing of livestock products is still primarily fragmented and unstructured even after decades of planned economic development.

Weak value chain system and the weak market linkage are the prime factors encountered in traditional marketing structures. In current scenario of FPO, Producer companies are very much helping small farmers to emerge in the market.

- The farmer producer organisations (FPOs) affiliated with the producer enterprises are the best illustration of collective efforts. Revenue has increased and costs have decreased as a result of the value chain's (VC) collaborative actions.

- FPOs has the capability of addressing and overcoming these traditional issues concerned with value chain as they are supported by relevant stakeholders and group members together. In this competitive situation, FPOs are emerged as a kind of new business models for the rural farmers.

Many FPOs (related to livestock farming) at village/district/state level collectively pool produce of primary producer and act in the value chain by direct dealing with either retailers or to the consumers with the help of NGOs, government and other relevant institutions. Thus, envisaging the concept of collectivization and benefitting.

Conclusion

Marketing channels remained traditional and is still in certain areas creating a low margin income for the farmers. FPOs in collaborating with their farmer members helps to overcome the traditional marketing barriers and the support from relevant stakeholders, governments and other institutions made FPOs benefitted in all the aspects (production to distribution). By combining produce, adding value, and creating market connections, FPOs, in general, plays a critical role in strengthening value chains. This eventually improves the income and financial stability of its member farmers. Overall, FPOs serve as important intermediaries in the livestock value chain, bridging the gap between smallholder farmers and market opportunities while promoting sustainable and inclusive development in rural areas.

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Chapter 7

Pigging Out for Prosperity: Tracing the Pig Farming Value Chain

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The pig industry in India is gaining significant traction due to the rising demand for pork both domestically and internationally. Once concentrated in the northeastern region, pig farming has now become a popular choice among farmers nationwide because it requires low initial investment, offers high profitability, boasts high prolificacy, matures quickly, has a short generation interval, and benefits from growing pork demand.

India has a pig population of around 9.06 million (BAHS, 2019), which is mainly raised through traditional small-scale, subsistence-driven farming systems (Chauhan et al., 2016). Pigs make up 1.7% of the total livestock in the country. Compared with the 2012 livestock census, the overall pig population has dropped by 12%. Around 90% of pig population is confined to rural regions and 10% in urban areas. Out of total population of pigs, 79% are indigenous or non-descript and twenty-one percent are exotic or cross-bred. Assam leads the country in pig production in India with 2.10 million, followed by Jharkhand (1.28 million), Meghalaya (0.71 million), and West Bengal (0.54 million). Chhattisgarh, Uttar Pradesh, Nagaland, Bihar, Karnataka, and Mizoram are the remaining significant contributors. As demand for pork continues to rise; pig farming presents a promising opportunity for farmers across the nation. Pork makes for around 5% of India's total meat production. Currently, the market price for a live weight pig in Northern India ranges up to Rs 210 per kg (More than Rs 250/Kg live weight in

NE states), meaning that a farmer may earn more than Rs 20,000 for a 100-kilogram pig that is 7-10 months old. Farmers are enticed to pursue pig farming by the high benefit cost ratio (>1.5), short interval, and simple market.

Interestingly, pork production is being carried out in two extreme types of farming production systems viz. the intensive and backyard pig production systems. Goals, beneficiaries, inputs, outputs, and technological connections are all significantly different between these two systems. Both pig production systems are operated by pig farmers with huge differences in their education and income levels.

Backyard Pig Production System	**Intensive Pig Production System**
Objectives	
• To provide source of livelihood for small, marginal and landless rural farmers. • To provide meat and essential protein to the individual households • To provide nutritional security to the rearing families. • To provide valuable cash to their owners and improve socio-economic status of the farmers. • Employment generation in rural or marginalized areas and utilization of family labour in a more efficient way. • To meet unexpected needs in the family or to provide support in times of financial hardships. • Poverty alleviation at the national level.	• To increase farm income and profits. • To meet the increasing demand of animal protein by burgeoning human population. • To produce export quality pork and pork products and to capture international markets. • To improve technical efficiency of pig production. • To obtain high economic returns with the given inputs. • To upgrade traditional backyard pig rearing units to large profitable commercial farms. • To create employment opportunities by developing a large market chain across the country.
Beneficiaries	

• Small and marginal farmers • Rural women and children • Poor malnourished families • Small brokers or traders • General public and rural communities due to the consumption of household waste and improved environmental hygiene • Pork consumers in the rural areas • National economies as the backyard farms constitute a great role in national food production and enhance small farmer's income in the developing countries • Backyard pig production is beneficial for poverty alleviation in many parts of the developing world • Country as a whole due to preservation of indigenous pig breeds	• Progressive and large farmers • Subsidiary pig industries such as feed manufacturing industry, slaughter house workers and other processing industries workers • Importers and exporters of pork • Pig breeders • National economies due to rising exports • General public and pork consumers particularly in the urban areas • Crop farmers through availability of manure byproducts and no crop damage by free-range pigs • Herd health managers, veterinarians and other occupational workers • Drug manufacturing companies through sale of antibiotics and other growth promoters • Countries due to self-sufficiency in pork production and food security • Vaccine manufacturing companies
Value chain (Inputs and outputs)	
Inputs	
• Low level of inputs • Indigenous pig breeds • Low-cost housing • Limited space, where all types of animals-male, female, piglets are kept together in	• High level of inputs • High yielding exotic breeds • High-cost housing (separate pens for sow, boar, piglets etc.); capital-intensive

free ranging areas. • Crop residues or kitchen waste • No or minimal feed costs. The type of feed primarily depends on ~~the~~ availability rather than nutritional requirements (Lemke et al. 2007). • Family labour • Minimal veterinary support (minimum vaccination and medication costs) • No or minimal marketing and transaction costs	• Land costs • Labour (highly labour intensive) • Modern infrastructure and equipment • Premium quality feed (for different animal categories) • Herd health manager/veterinary services • Quality control and marketing manager • Vaccines, antibiotics, growth promoters and other medicines • Marketing and transaction costs • Controlled environment costs
Output	
• Additional cash for school fees, medical treatment, or small investments (Emebet et al., 2017; Yeshambel and Bimrew, 2014). • Increase in family income through sale of pork and pork products • Part-time self-employment • Improved nutritional status of rural households • Leisure time through slaughter of pigs and consumption of pork on festivals and other special occasions • Gift of pigs as dowry to the married couple	• High quality pork and pork products • Improving the export-import balance • Income generation for pig farmers • Employment generation • Food safety and security • Manure production • Development of subsidiary industry • High-yielding breed piglets • Source of cooking fats, bristles, bone and blood meal to commercialized industries

• A financial safety net to fulfill a role in cultural traditions	
General	
• Low-input low-output system • The backyard pig production system utilizes the traditional wisdom; therefore, the latest scientific inputs are minimal. • It converts household waste and crop residues to nutritious animal protein but with a poor feed-conversion ratio. • It presents an environment friendly way to convert kitchen/ household wastes into quality meat and does not compete with humans for food. • Depends on locally available feeds or household wastes with minimal feed or veterinary costs. • Overall, this system requires less mechanization or technology driven inputs. • It is primarily based on the indigenous pig breeds.	• High-input high-output system • Intensive pig production is driven by growing demand and market opportunities (Steinfeld et al. 2006) • High intensity of feed use and a higher feed-conversion ratio (Steinfeld et al. 2006) • Other driving factors include transport costs, disease concerns, environmental regulations, and other policy concerns (Steinfeld et al. 2006) • Good manufacturing practices (GMP) • Increasing scales of production • Enhanced biological and managerial efficiency • Vertical integration of pig production and development of production chains • Improved animal welfare and care

(Singh and Singh, 2019)

Pig Farming Value Chain refers to the series of activities and processes involved in the production, processing, and distribution of pigs and pork products. Value chain analysis or mapping is a quick and useful method for understanding pig production systems, especially new ones. This mapping outlines the various interconnected activities and actors involved in the input and output value chain of the pig production system. It encompasses all the interlinked activities

and factors from procurement and production to delivery to the final consumer (Porter, 2008). Additionally, value chain mapping helps identify different "risk nodes" within the production system, which make the supply chain vulnerable to diseases and hazards. Identifying these risk nodes is crucial as it enables organizations or disease control authorities to proactively mitigate risks and enhance the value chain's resilience, particularly during challenges like the African Swine Fever disease impacting a nation.

Depending upon farming system, there exist different types of value chains. In non/less pork consuming states like North Indian states (Punjab, Haryana, UP), intensive pig farming within farm feeding system with feed or kitchen waste are practiced and live pigs are then transported to pork consuming North-eastern states. In pig value chain of these states, one additional chain to transport the live pig to consumer states also exists.

Pig Farming Value Chain in North India

Input Value Chain

The majority of pig farmers were rearing Large White Yorkshire breeds with variable and continuously changing animal numbers. Pig farmers buy piglets from local sources utilizing their own expertise. They feed the pigs kitchen waste collected from places such as the hotel industry, mess halls, marriage venues, and vegetable markets. Three common feeding practices include feeding kitchen waste exclusively, feeding only concentrate, and a combination of both kitchen waste and concentrate. Many farmers prefer readymade feed because dealers often deliver it directly to their farms. etc. Pig farmers usually treat their sick animals themselves, with only a few consulting authorized veterinarians. Many pig farmers handle vaccinations, deworming, castration of male pigs, iron injections for piglets, and needle teeth cutting on their own. Most of the farm management is done either by the farmers themselves, with the assistance of family members, or with the help of labourers for daily tasks (Fig. 1)

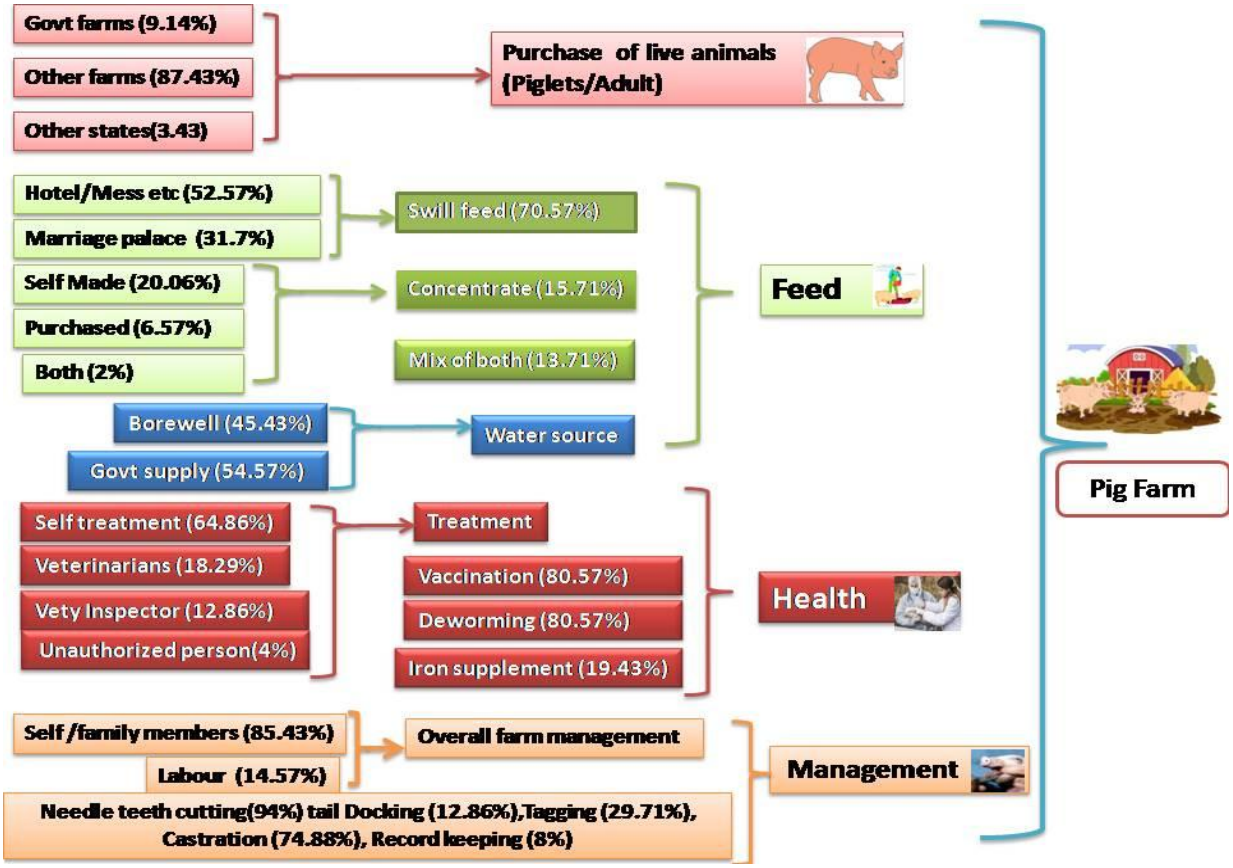

Fig. 1: Outline of input value chains created based on interview with 350 pig farmers and 15 Key informants (Singh et al, 2024)

Output Value Chain

Most pig farmers sell their pigs to traders, other farmers, and local butchers. Some farmers act as middlemen, selling pigs to traders. The main value chain in the pig industry involves Farmers – Traders - North East market - Consumers. Other value chains, such as Farmer - Farmer - Traders - Consumer and Farmer - Butcher - Consumer, are less common. Farmers typically rely on other farmers, farmer associations, middlemen, and others for market rate information. Although Standard Operating Procedures (SOPs) exist, their strict adherence is questionable, as evidenced by the spread of African Swine Fever from the North-eastern states to the entire country Only a small number of farmers add value to pork by making products such as salami, peda/kebabs, and pork sausage. Most farmers slaughter pigs themselves, while others

enlist the help of butchers. Butchers purchase live pigs from farmers without health certificates, slaughter them at their shops or homes without protective measures, and never condemn the pork. The same tools and surfaces are used to cut meat from various species. Farmers dispose of carcasses away from the farm either by burial or by throwing them in the open. Placentas are disposed of by burial, open disposal, or by throwing them into drainage. Excreta are disposed of in open areas, by burial, or by throwing it into drainage. Some farmers use dung as manure in their fields (Fig. 3)

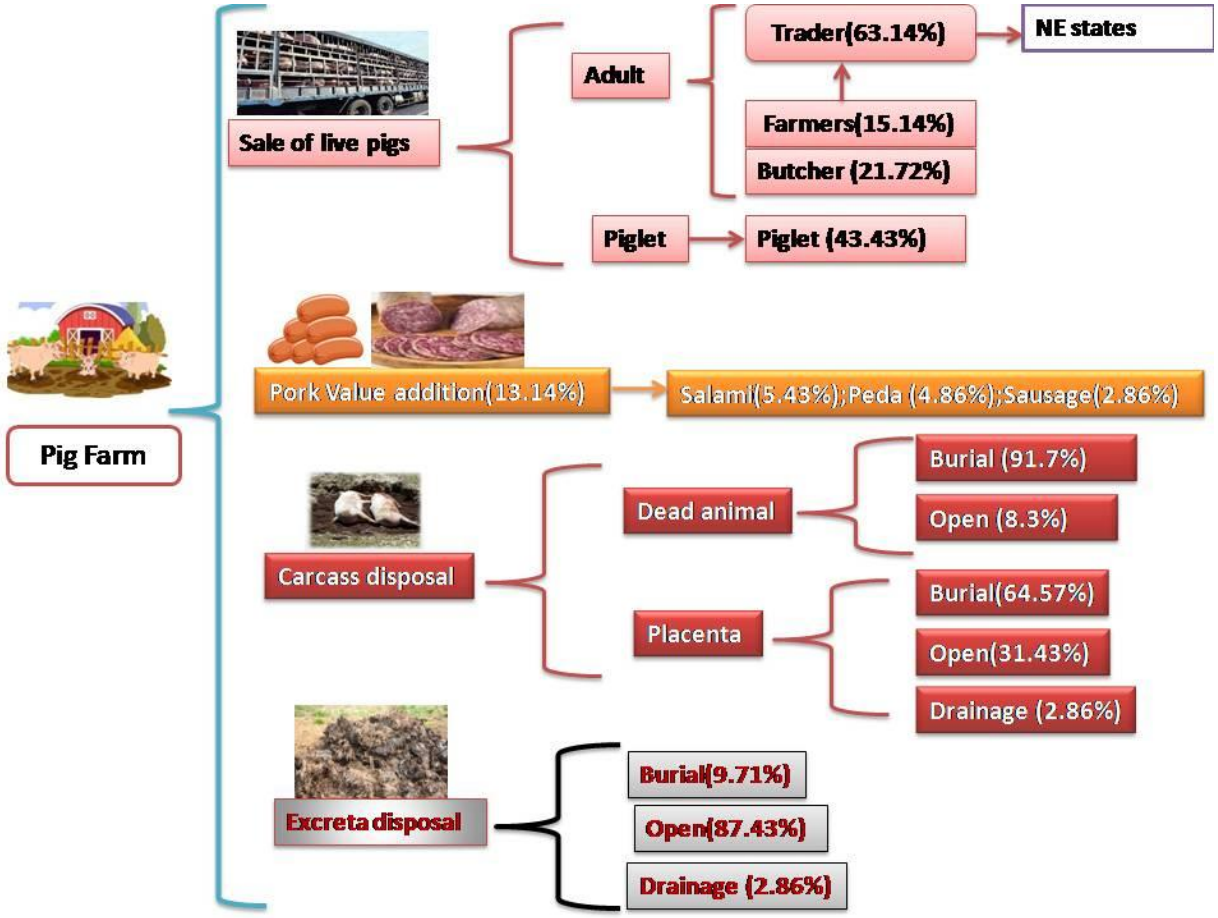

Fig 2: Outline of Output Value Chain created based on interview with 350 pig farmers and 15 Key informants (Singh et al., 2024)

Risk Spots Analysis in the Value chain

There are multiple risk points where infectious or zoonotic diseases can infiltrate a pig farm. Identifying these points can help prevent the spread of infectious diseases to other areas by various means (Fig. 3). Post-purchase, unhygienic practices and non-quarantine measures at the farm may predispose the farm to the entry of pathogens and diseases. Some of the risk spots are mentioned as below:

- Farmers do not use quarantine practices when introducing newly purchased animals into the farm.

- Farmers do not provide separate pens after the purchase of the new pigs before mixing them with other pigs, unlike the rest.

- Farmers do not follow an isolation regimen for sick animals to ward them off from spreading infections to the other livestock on the farm.

- Farmers do not take any disinfection measures during transport of newly purchased pigs. Farmers do disinfect vehicle tyres before entering the farm thereby predisposing the farm to the spread of inter-farm infection.

- Feed suppliers deliver feed to multiple pig farms on the same day without following any biosecurity measures, which could increase the chances of inter-farm contamination.

- Farmers do not use any ectoparasiticide on their pigs at farms.

- Farmers do not vaccinate their pigs against Foot and Mouth Disease (FMD) and Classical Swine Fever (CSF).

- Pig farmers assist sows during their farrowing with bare hands.

- The use of Personal Protective Equipment (PPE) by farmers, middlemen/ traders/visitors/butchers is almost non-existing (Khanal and Poudel, 2017).

- Farmers do not provide foot baths at farm entry, which is essential to control the entry of pathogens/infection into the pig farm.

- Farmers do not restrict entry into the farm premises. Unauthorized entry, no provision of PPE, or other safety measures may lead to the entry of any infection or pathogenic variant into the farm, so it becomes utmost important to restrict undesired entries into the farm

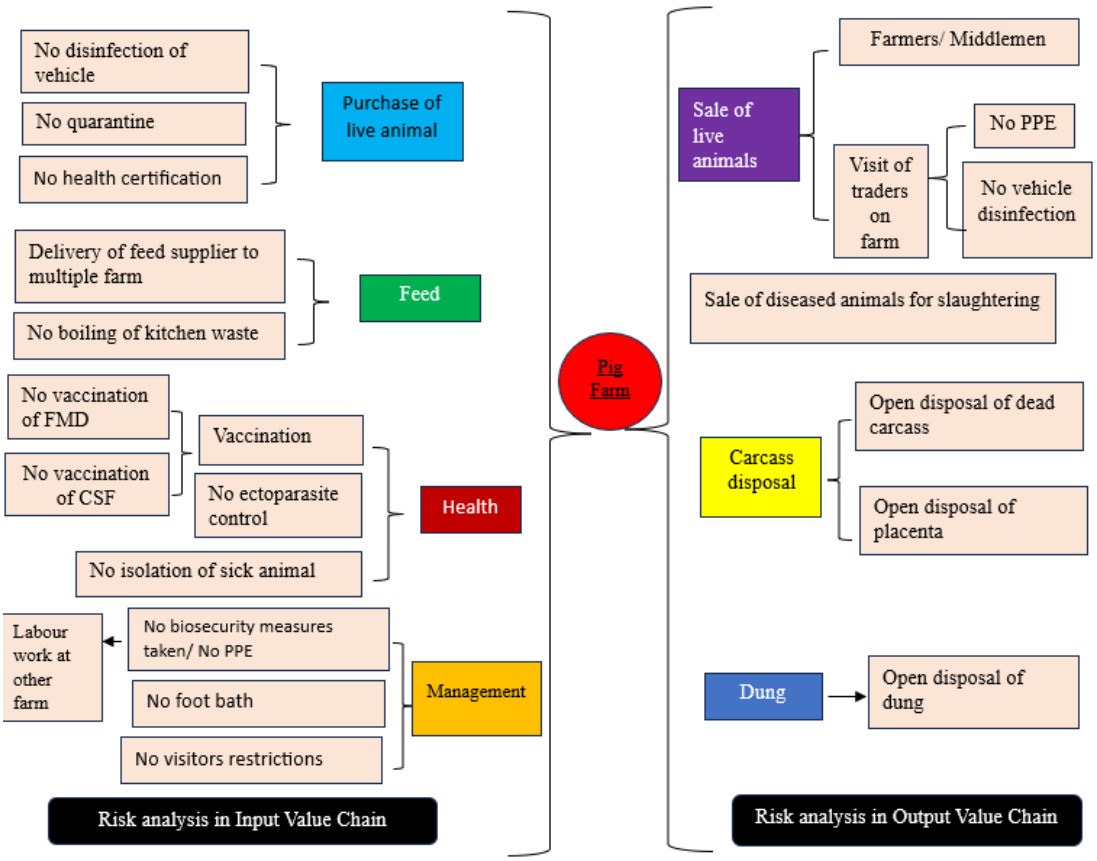

Fig. 3: Outline of Risk Spot Analysis in the Value Chain (Adopted & modified from Singh et al., 2004)

- A diseased animal could pose an economic loss to the farmer if mortality occurs. Out of the total respondents who are doing value addition, a few farmers also slaughtered diseased animals. This may be due to the non-availability of pig health services at the time (Ogbuewu et al., 2012)

- Farmers dispose of the carcass of a dead pig in open areas. Similarly, farmers also dispose of the placenta by an open disposal method.

- Unregulated slaughter houses in residential areas, slaughtering infected pigs near roads or water sources without following proper protocols or wearing protective equipments, inconsistent and erratic disease prevention and use of swills from restaurants and kitchens as pig feed are some other risk spots (Tuan, 2021).

Pig Farming Value Chain in North-east India

In North-east India, the pig business is primarily unorganised. Backard type pig farming with local/indigenous breeds predominates in these states. Smallholders sell their pigs to intermediaries at their doorstep, and the pigs eventually end up in unorganised marketplaces where no documented sales history is kept. Traders, butchers, and pork vendors travel to local villages to acquire pigs. Live pigs from Assam are even sold to neighbouring states like Arunachal Pradesh, Meghalaya and Nagaland. Producer-Wholesaler, Producer-Retailer and Producer-local trader-wholesaler are the main marketing channels (Sunil *et al.*, 2021). Retail pork establishments predominate in NE states to cater to the needs of consumers without giving much attention to hygiene. Pork is in great demand, yet there aren't many well-established value chain participants. Consequently, a number of entrepreneurs are venturing into pig farming to close the gap between supply and demand. Government and donor agencies are supporting the pig sub-sector in North-eastern India through research-based information, improved breeding stock, production training, extension services, and credit facility through promoting Self Help Groups.

Overall, the primary participants in the pig value chain include farmers, traders, butchers, suppliers, veterinarians and consumers. In the northern part of the country, Farmers – Traders – North East market – Consumer is the predominant chain. For marketing purposes, the pig farming industry relies heavily on traders or butchers. Progressive producers, particularly breeders, often seek veterinarian's help to treat their animals, whereas small producers typically attempt to treat their animals on their own, frequently using human medicines or traditional remedies. In many areas of North-east India, veterinary services are almost non-existent, and there is generally a very low level of awareness among producers regarding pig diseases and preventive measures (Write *et al*., 2010).

Due to a lack of health facilities, pig farmers are forced to self-treat or butcher their pigs. The implementation of biosecurity and personal protective measures is nearly non-existent. Many risk areas may exacerbate inter-farm disease transmission. This makes pig farming more susceptible to infectious diseases such as Classical Swine Fever and African Swine Fever. Outreach initiatives aimed at stopping the spread of infectious illnesses and producing healthy meat should involve farmers /traders'/ veterinarians'/transporters/ and butchers.

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Chapter 8

Wings to Wealth: Decoding the Dynamics of Poultry Farming's Value Chain

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Poultry farming has emerged as a critical component of the agricultural sector, contributing significantly to food security, nutrition, employment, and income generation, making it a key contributor to the worldwide economy. From small-scale farms to huge commercial organizations, it provides employment to millions of farmers worldwide. The Indian poultry industry has evolved into a dynamic, more organized industry over the last 20 years. The poultry business is currently reaching new heights on a day-to-day basis by implementing all the structured techniques nearly at every level (Nanda *et. al.,* 2022). The poultry industry in India significantly contributes to the GDP of the country's livestock sector. Currently Indian poultry sector globally standing third in egg production with 133.38 billion (BAHS, 2021) and fifth in meat production with 9.77 million tonnes (BAHS, 2021).

The value chain of poultry farming encompasses several stages; from hatcheries to feed production, farming practices, processing, marketing, and distribution. The process of creating, promoting, and delivering a product to the final customer is understood through the application of value chain analysis. This analysis aids in the identification of the different phases, distribution routes, stakeholders, and procedures involved in the production and sale of poultry products for the poultry business (Bukachi *et. al.,* 2024). Understanding the dynamics of this value chain is essential for maximizing efficiency, minimizing risks, and enhancing profitability in the sector. This chapter aims to decode the complexities of the poultry farming value chain, examining key nodes, bottlenecks, and opportunities for value addition.

Poultry Value Chain: An Overview

The poultry value chain analysis deals with range of practices from farm to fork level initiating from inputs (breeding stock, equipment and feed suppliers, veterinary aid) to production (feeding, healthcare, breeding and general management) followed by processing (grading, packaging, standardization, quality control), distribution (adopting marketing channels) and ultimately to consumption by consumers. Each step of value chain possesses suitable impact on quality end product (Udoye *et. al.,* 2024). Value chain analysis helps in understanding different challenges like feed prices and market price fluctuations, credit and finance access to farmers, market logistics and hence analyses the creation for opportunities regarding technological advancements in management, expansion of import as well as export, value addition, increasing supply during high demand. The high input cost, climatic conditions and the high price of chicks are found to be the main challenges in the backward poultry value chain, and disease outbreaks, cost of packaging and poor storage system are the main challenges in the forward value chain (Singh *et. al*., 2022). Addressing different challenges and creating suitable opportunities can increase the farm output qualitatively and quantitatively (Bukachi *et. al.,* 2024). Stakeholders can improve production and profitability in the poultry industry by identifying areas for improvement, increasing efficiency, and improving general understanding of the value chain.

Value chain research reveals notable diversity in the kinds of different value chains exist in the poultry industry. Compared to the value chains for broilers and native birds, the value chain for layers and eggs are typically much longer and more dispersed. In the case of broilers, shorter chains indicate a higher degree of integration between stakeholders via formal and informal contractual arrangements (Herve *et. al.,* 2024). Conversely, in the case of indigenous poultry, the majority of trade is conducted directly between farmers and customers, who can include other farmers and merchants.

Poultry value chain includes several interlinked components:

- **Input Supply:** This includes hatcheries, feed suppliers, and veterinary services. The availability and cost of high-quality chicks, feed, and medications directly impact production levels and profitability.

- **Farming Practices:** At the core of the chain is poultry farming, where the efficiency of rearing practices determines the yield of eggs and meat. Factors like housing, biosecurity, feeding regimes, and disease management are critical to maintaining productivity.

- **Processing and Packaging:** After production, the poultry undergoes processing, including slaughtering, cleaning, cutting, and packaging. This stage adds value to the raw product, making it suitable for various market segments.

- **Marketing and Distribution:** This involves wholesalers, retailers, and direct sales to consumers. Effective marketing strategies and distribution networks are vital to reaching a broad customer base and ensuring product availability.

Components of Poultry Value Chain

1. **Procuring Chicks: The Foundation of Poultry Farming**

The first stage of the poultry farming value chain begins with acquiring day-old chicks. The quality of chicks plays a crucial role in determining the productivity and profitability of the entire operation.

- **Selecting Reliable Hatcheries:** The selection of a reputable hatchery is essential. High-quality chicks, free from disease and genetic defects, are vital for ensuring low mortality rates and optimal growth. Hatcheries provide not only chicks but also essential information on rearing practices, vaccinations, and feeding.

- **Chick Transportation and Handling:** Safe and efficient transportation of chicks from the hatchery to the farm is crucial to prevent stress, injury, or mortality. Appropriate containers, ventilation, and temperature control during transport are essential.

2. **Brooding and Rearing: The Early Growth Phase**

Once the chicks arrive on the farm, the brooding stage begins. This phase focuses on providing the right environment, nutrition, and cares to ensure healthy growth.

- **Brooding Setup:** Brooding involves maintaining optimal temperature, humidity, and lighting conditions to provide a comfortable environment for young chicks. Proper brooding practices minimize mortality rates and promote uniform growth.

- **Feeding Practices:** High-quality starter feed is critical during the brooding phase. The feed must contain balanced nutrients viz. proteins, carbohydrates, fats, vitamins, and minerals, to support rapid growth and development. Access to clean water is equally important.

- **Health Management:** Regular monitoring for signs of illness, vaccination against common diseases, and maintaining biosecurity measures are vital during this period to prevent outbreaks.

3. Growing and Finishing: From Chicks to Market-Ready Birds

The growing and finishing stages involve raising the birds until they reach marketable weight or egg-laying maturity. Effective management practices during this phase significantly impact productivity and profitability.

- **Housing and Environment Control:** Proper housing ensures adequate ventilation, lighting, space, and temperature control. Intensive and semi-intensive systems must prioritize comfort and reduce stress, which affects growth rates and egg production.

- **Feeding and Nutrition:** Feed formulations change according to the age and purpose (meat or egg production) of the birds. The finishing phase requires feed that enhances weight gain or egg-laying capacity, ensuring the most cost-effective conversion rates.

- **Disease Prevention and Control:** Disease outbreaks, such as Avian Influenza and Newcastle Disease, can be devastating. Preventive measures include regular health check-ups, timely vaccinations, and strict hygiene and biosecurity protocols to minimize the risk of infection. A very few backyard poultry farmers vaccinate their birds, as most farmers are unaware of the importance of immunization. Although some local breeds have genetic resistance to certain diseases, they remain susceptible to many common poultry illnesses, stressing the need for state and central animal husbandry departments to implement effective vaccination policies (Chadda, 2024).

4. Processing and Packaging: Adding Value

Once the birds reach market weight, the next stage is processing, where raw poultry is converted into market-ready products. This stage adds significant value to the poultry products and caters to diverse consumer preferences.

- **Slaughtering and Processing:** This involves humane slaughtering practices followed by plucking, cleaning, and evisceration. Further processing may include cutting, deboning, and preparation of value-added products such as sausages, nuggets, or ready-to-eat meals.

- **Packaging:** Packaging is critical to preserving the freshness, safety, and quality of poultry products. It involves using materials that extend shelf life, prevent contamination, and attract consumers.

5. Marketing and Distribution: Reaching the Consumer

Marketing and distribution are key components that determine the success of poultry farming. Efficient channels help in reaching a broader market and fetching competitive prices.

- **Market Access:** Small-scale farmers often face challenges accessing larger markets due to limited infrastructure, fluctuating prices, and inadequate market information. Cooperative societies, digital platforms, and e-commerce channels can enhance market access and transparency.

- **Distribution Networks:** Effective distribution requires a well-organized network that includes wholesalers, retailers, and direct sales to consumers. Cold chain logistics play a crucial role in maintaining product quality from farm to fork.

6. Consumption: Meeting Diverse Dietary Needs

Poultry products, primarily meat and eggs, are consumed worldwide, providing a rich source of protein, vitamins, and minerals.

- **Consumer Preferences:** Consumer demand for poultry products varies based on cultural, regional, and economic factors. Understanding these preferences allows producers to tailor products to meet local tastes, such as free-range eggs, organic chicken, or processed meat products.

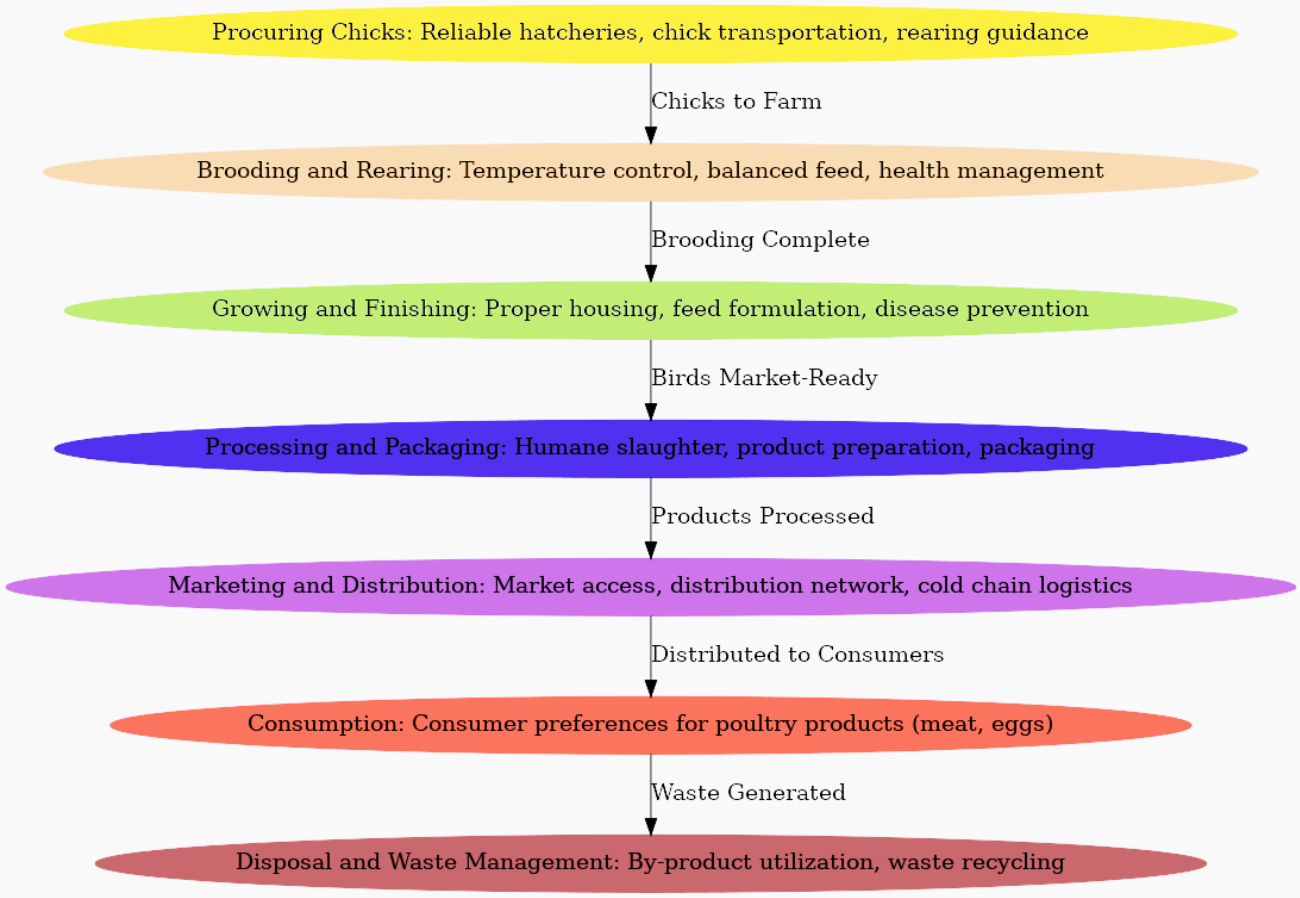
- **Health and Safety Standards:** Meeting health and safety standards is vital to maintaining consumer trust and market access. Compliance with food safety regulations, proper labeling, and certification are essential.

7. Disposal and Waste Management: Sustainability Focus

The final stage of the value chain is the disposal of waste products, which, when managed effectively, can create additional value and ensure environmental sustainability.

- **By-Product Utilization:** Poultry farming generates by-products such as feathers, blood, offal, and manure. These can be converted into animal feed, fertilizers, biofuels, or other value-added products, reducing waste and creating new revenue streams.

- **Waste Management:** Proper disposal methods, such as composting or anaerobic digestion, help manage waste and reduce environmental impact. Farms can adopt sustainable practices to minimize carbon footprints and promote eco-friendly farming.



Components of Poultry Value Chain

Bottlenecks in the Poultry Value Chain

Bottlenecks	Description	Potential Solutions
Input Supply	Inconsistent supply of essential inputs like day-old chicks, vaccines, and medicines	Development of reliable supply chains and distribution networks for poultry inputs
Feed Quality	Limited access to quality feed or reliance on homemade feed, which is nutritionally inadequate	Improvement in feed supply chain, promotion of the use of nutritionally balanced economical commercial feeds, and training of farmers on feed formulation.

Veterinary Services	Lack of access to skilled veterinarians and inadequate veterinary care, leading to poor flock health.	Increase availability of veterinary services, offer mobile veterinary clinics, and train local health workers.
Market Access	Difficulty in reaching markets due to poor infrastructure or lack of market information.	Develop better transportation infrastructure, establish local markets, and provide market information to farmers.
Financial Support	Limited access to credit or financial services for investment in poultry farming.	Facilitate access to microfinance and credit schemes, and provide financial literacy training to farmers.
Poultry Housing	Inadequate or poorly constructed poultry houses, leading to poor living conditions and higher mortality rates.	Promote the construction of proper poultry housing with ventilation and sanitation facilities.
Disease Management	High incidence of poultry diseases due to inadequate preventive measures and lack of vaccination.	Implement regular vaccination programs and educate farmers on biosecurity measures.
Knowledge and Skills	Limited knowledge and skills in modern poultry management practices among farmers.	Conduct training and extension programs on best practices for poultry management.
Input Supply Chain	Inconsistent supply of essential inputs like day-old chicks, vaccines, and medicines.	Develop reliable supply chains and distribution networks for poultry inputs.
Environmental Factors	Poor environmental conditions affecting poultry health and productivity, such as inadequate sanitation and waste management.	Improve waste management practices and promote better sanitation in poultry farms.
Processing Facilities	Lack of facilities for processing poultry, leading to post-harvest losses and reduced value.	Invest in local poultry processing facilities and promote value-added products.

Chadda, 2024

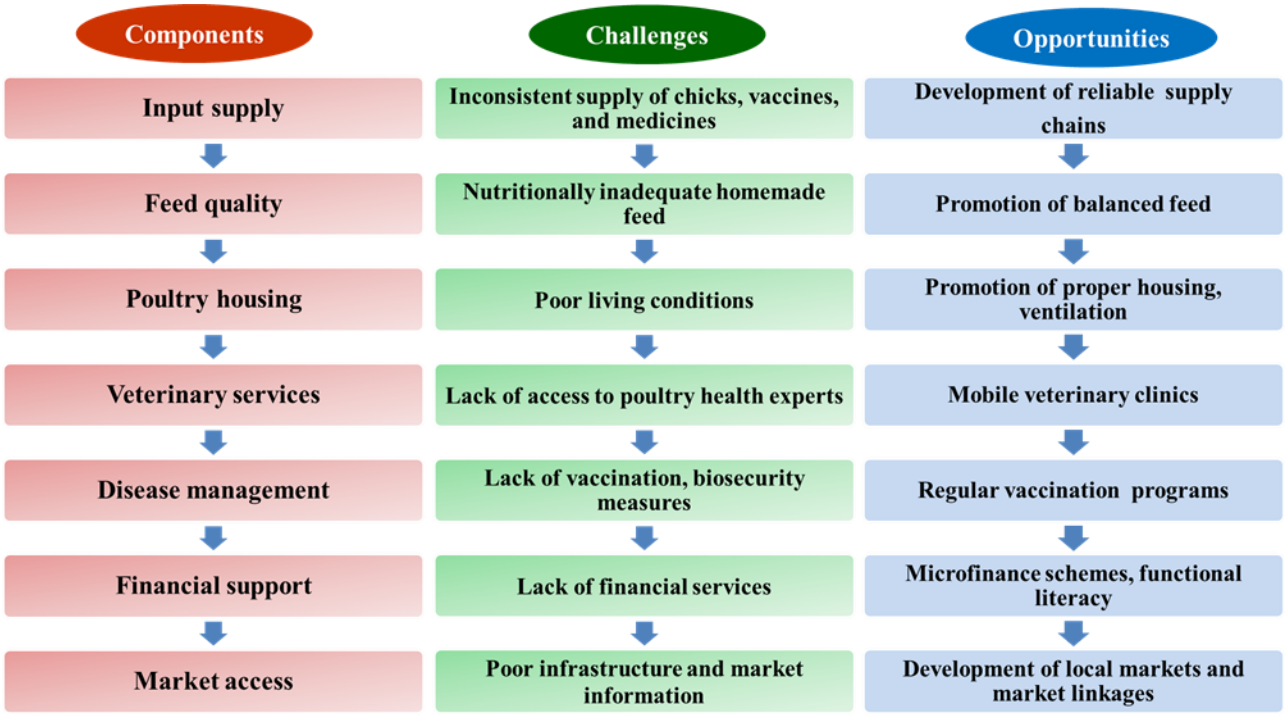
Opportunities for Value Addition

Poultry farming offers multiple opportunities for value addition, enhancing profitability across the value chain:

- **Product Diversification:** Beyond fresh meat and eggs, there is potential for processing poultry into value-added products like sausages, nuggets, and ready-to-eat meals. The demand for such products is rising due to changing consumer preferences and increased urbanization.

- **By-Product Utilization:** Poultry by-products, such as feathers, blood, and offal, can be converted into products like animal feed, fertilizers, and biofuels. This approach not only reduces waste but also creates additional income streams for farmers.

- **Technology Adoption:** Technologies like automated feeders, climate-controlled housing, and digital monitoring systems can optimize production and reduce labor costs. Mobile applications and platforms that provide real-time market data, disease alerts, and farming tips can empower farmers to make informed decisions.



Key Components, Challenges, and Opportunities in Backyard Poultry Farming

Strategic Recommendations for Strengthening the Poultry Value Chain

To harness the full potential of the poultry farming value chain, several strategic interventions are necessary:

- **Capacity Building and Training:** Providing farmers with training on best practices, disease management, and biosecurity can improve productivity and reduce losses. Extension services play a crucial role in disseminating knowledge and innovative practices.

- **Access to Finance:** Facilitating access to credit and financial services for small and medium-scale poultry farmers can enable them to invest in quality inputs, technology, and infrastructure, thereby improving production efficiency.

- **Policy Support:** Governments need to create an enabling environment through policies that support market access, reduce input costs, and promote sustainable practices. Public-private partnerships can be instrumental in achieving these goals.

Conclusion

Decoding the dynamics of the poultry farming value chain reveals a complex interaction of factors that influence its efficiency, profitability, and sustainability. Addressing the challenges and leveraging the opportunities within the value chain require a multi-faceted approach involving stakeholders from farmers to policymakers. With strategic interventions, poultry farming can continue to be a vital driver of rural development, food security, and economic growth.

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Chapter 9

Farm to Feast: Tracing the Journey of Meat and Egg

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The term supply chain is simply described as the physical flow of material from one enterprise to another. In today's health-conscious society, there is an increasing need for meat that is produced sustainably, ethically, and locally. In the meat and egg industry, the "farm to feast" idea encompasses the products complete journey from the farm to the consumers plate. This concept focuses on transparency, traceability, and promoting a deeper understanding of from where our food comes into existence. It encourages the thought of shortening the supply chain and establishing direct contact between farmers and consumers. It highlights the value of locally obtained ingredients, the craftmanship of farmers, and the advantages of greater connections between producers and consumers. In India, meat production is largely a byproduct of livestock production. Majority of large animals used for meat production (buffalo and cattle) are aged or spent animals that have completed their productive and reproductive lives. However, goats, sheep, pigs, and poultry are specifically raised for meat production. Buffaloes are used as quadruple purpose animals in most sections of the country, providing milk, meat, and draught. Cow and bullock slaughter is banned and varies state to state. Pigs are exclusively meat animals raised mostly by the poorer sectors of society and tribal groups. Broiler chicken contributes significantly to meeting the increasing need of growing populations. This has led to an interesting dynamics of supply chain which affects the production immensely and act as a driver of growth, particularly in animal sector.

Various stages involved in supply chain of meat

The stages can be broadly divided into the following phases: Breeding and rearing, feed and nutrition, health management, transportation, processing and slaughter, packaging, distribution, retail and finally, consumer use. Each stage involves careful planning and execution to maintain the integrity of the meat supply chain.

1) **Animal rearing:** The journey starts on breeding farms, where cattle, pigs, and poultry are selectively bred to improve desired qualities like growth rate, meat quality, and disease resistance. Advanced genetic procedures and selective breeding programmes are utilized to ensure that the animals are well-suited to meat production. The breeding procedure entails carefully selecting parent stock in order to produce offspring with industry-standard meat quality and yield. During the rearing stage, the animals are kept in environments that promote their growth and development. Depending on the species and production methods, these can be pasture-based systems, feedlots, or intense indoor farming. Farmers prioritize enough shelter space and conditions that enhance animal welfare and optimal growth.

2) **Feeding & nutrition:** Animal feed is critical to the quality and nutrition of meat produced using sustainable farming practices. The feed is carefully balanced to supply the animals with the proteins, carbs, fats, vitamins, and minerals they require to grow and develop properly. Choosing non-GMO and organic feeds is consistent with sustainability objectives and promotes a more natural and wholesome approach to animal feeding. Forage-based diets can improve the nutritional value of meat by raising levels of omega-3 fatty acids and other important elements. The type of feed and the feeding procedures used have a considerable impact on the final quality of the meat, influencing parameters like as tenderness, flavour, and fat content.

3) Animal welfare: Ethical Treatment: Animal welfare is crucial to the farm-to-feast journey. Animal welfare encompasses five freedoms; namely freedom from hunger and thirst; freedom from discomfort, pain, injury or disease; freedom to express normal behaviour and the freedom from fear and distress. These freedoms are frequently violated because, prior to killing, animals are subjected to physical and psychological stimulation stresses through human-animal or

animal-animal interactions. These events include handling, loading, transportation, waiting in lairage, feed deprivation, crowding, noise, stocking density, poor handling facilities, and extreme temperatures. Although animals may be adapted to the harsh environment during their lifetime at the farm, these procedures pose a major challenge on their welfare and subsequently the quality of meat available to the consumers.

4) Transportation: Once the animals reach the appropriate size and weight for slaughter, they are transported to the abattoir. Typically, methods used to move animal are on hoof, by road, by rail, on ship and by air. Transport of livestock is undoubtedly the most stressful and injurious stage in the chain of operations between farm and slaughterhouse. Having selected the preferred mode of transport of slaughter animals, it is necessary to take in to account numerous factors such as: type of vehicle, ventilation, floor space, floor type etc. the other factors to be considered during journey, in order that the animal do not suffer, become injured or die are as follows: Trekking (planning the distance to be travelled, opportunities for grazing, watering, overnight rest), time of day of transport, duration of journey, driving rules to be followed, wind chill etc. The logistics chain is made up of the operations and activities that take place from the farm to the abattoir. Effective logistics are essential for ensuring that livestock arrives at the abattoir on time and in good condition. This includes organizing schedules and routes in order to reduce transportation timing and associated animal stress.

5) Slaughter and Processing: When converting food animals into consumable products or valuable by-products, it is required to slaughter the animal humanely and handle its carcass in a hygienic and effective manner. In order to reduce pain, the slaughtering procedure is usually swift and monitored by trained experts. Following the slaughter process, the carcasses proceed through a number of stages, such as skinning (or, in the case of pigs, scalding and dehairing), freezing, and evisceration. Veterinary inspectors examine the carcasses to make sure they are disease-free and safe for human consumption. A crucial checkpoint for guaranteeing the safety and quality of meat is the inspection procedure.

6) Packaging: Following processing of the carcasses, the meat is cut into different portions and packaged. In addition to extending the meat's shelf life and protecting it from contamination,

packaging also informs consumers about the contents. In order to preserve freshness and avoid spoiling, innovative techniques such as vacuum packaging and modified atmospheric packaging are employed. Information on the sort of meat, weight, price, expiration date, and occasionally the meat's origin is included on the labels of meat packages. This data guarantees traceability across the supply chain and assists customers in making knowledgeable purchasing decisions.

7) Marketing of meat: Retailers of meat obtain the carcasses they need from wholesalers, abattoirs, or by purchasing live animals, having them killed in a slaughterhouse, and then delivering the primal meat pieces and carcasses to their store. Most meat is sold fresh, without chilling, through retail meat stalls the same day the animal is slaughtered. The majority of chickens are marketed through wet markets, where the live birds are positioned alongside retail establishments and are freshly killed, dressed, chopped, and distributed into polyethylene or polypropylene bags based on customer demand. In these kinds of stores, customers can select which birds to purchase. In large towns and cities, the sale of frozen and chilled beef in packs is gradually rising in supermarkets. Regarding broiler chicken, some modern integrated poultry processing facilities have started sourcing birds directly from their own and contracted poultry farms, selling the hygienically prepared chicken in urban areas and exporting it to other countries. In villages, sheep, goats, and buffalo are sold for retail use. This is done by killing one or two animals once a week, or more frequently on special occasions, when a group of people band together to split the cost of the animals and the meat they provide. In villages, there are not much overhead costs associated with meat.

8) Consumer use: When the meat is purchased, buyers store it in freezers or refrigerators until they are ready to prepare it. Sustaining the safety and quality of meat requires careful handling and storage. In order to prevent cross-contamination with other foods and to prepare meat at the proper temperature, consumers are encouraged to abide by food safety regulations.

Issues in meat supply chain:

- ✓ India has a poorly organized meat supply system, including slaughtering and selling carcasses to wholesale and retail establishments. Middlemen operate the market with

established business interests, which typically account for the majority of the overall price charged to customers. Four or five types of intermediaries exist between farmers/producers (in rural areas) and urban abattoirs, butchers, and meat shop operators.

- ✓ Lack of grading systems, highly perishable meat, religious taboos, greater variation in the regional agroclimatic conditions, inadequate cold storage facilities and refrigerated transport vehicles, seasonal fluctuations in meat prices, and scarce infrastructure facilities at slaughterhouses all contribute to the stakeholders' overall poor economic situation.

Journey of an egg: Various stages involved in the supply chain

The journey of egg from farm to feast is a complete and carefully managed process that ensures the eggs we consume are safe, nutritious and of the highest quality in each stage, from breeding and hatching to final consumer use, is critical in this complex supply chain.

Breeding & hatching

1) ***Selection of breeds:*** Egg production is the primary goal of breeding farms, which prioritize various attributes like as egg yield, size, shell quality, and general health while selecting and breeding chicken. When the chickens have laid fertilized eggs, the eggs are cautiously placed in incubators with precisely controlled humidity, temperature, and ventilation. The chicks hatch and are prepared to go to the brooding stage after around 21 days of incubation.

2) **Brooding**

a) **Raising chicks:** After hatching, chicks are placed in brooder houses, where they receive proper care, nourishment, and water. Since it lays the foundation for the chicks' development and potential for future egg production, this early period is crucial. The environment within the brooder houses is closely observed to ensure that the chicks are growing in a healthy manner, free from stress and illness.

b) **Pullet Rearing:** Chicks (now called pullets) are raised until they are 16–20 weeks old, or until they achieve maturity. They undergo growth, health, and development monitoring, and any necessary dietary and environmental changes are implemented. This stage is crucial to the growth of healthy hens that can provide eggs of superior quality.

c) **Laying phase:** The pullets are moved to layer houses when they are mature enough to become hens. Depending on the farming technique, different housing options are available, such as conventional cages, aviary systems, or free-range arrangements. These houses' environments are controlled to optimise egg production, taking into account the hens' general health, feeding schedules, and lighting. this stage, during which the hens begin to consistently lay eggs.

3) **Egg production & collection:** Every day, eggs are gathered manually or, in bigger companies, by automated methods. Automated systems guarantee that the eggs are efficiently collected and reduce handling. The eggs are collected and then taken to the processing facility, where they go through a number of stages of preparation before being sold.

4) **Egg handling and processing:** Before being processed, eggs are thoroughly washed and sanitized at the facility to get rid of any dirt or bacteria. Candling is the next step, in which eggs are examined under a light source to check for internal defects and assure quality. After that, the eggs are categorized into Grade A and Grade B groups according to their size, weight, and general quality. By grading the eggs, this procedure helps establish their market worth and guarantees that consumers will only receive products of superior quality.

5) **Packaging:** Following grading, the eggs are placed inside trays or cartons that are labelled with essential information including the grade, size, packing date, and expiration date. In order to safeguard the eggs during transit and give customers pertinent information, proper packaging is crucial. After being packaged, the eggs are kept in temperature-controlled spaces to preserve their freshness until they are sold in stores.

6) **Distribution:** After being packed, the eggs are sent from the farm or processing plant to a number of distribution locations, such as wholesalers, stores, or food service providers directly. In order to maintain the eggs' quality throughout transit, refrigerated vehicles are frequently utilized.

7) **Marketing:** Eggs are stocked and sold to customers in retail outlets like grocery stores and supermarkets. To preserve their freshness, eggs in these retail establishments are typically kept in refrigerator compartments. Eggs are marketed according to many characteristics that appeal to consumers as well as their type (such as organic or free-range).

8) **Consumer purchase & use:** Eggs are bought by people from stores and kept in refrigerators at home. Eggs are a great source of nutrients and a versatile culinary ingredient that can be utilized in a wide range of cuisines.

Issues in egg supply chain:

- ✓ Possibility of pathogen contamination during manufacture, processing, and distribution, such as salmonella.
- ✓ Keeping eggs fresh and of a consistent quality from the point of production to the point of sale.
- ✓ Exposure to disruptions from disease outbreaks (e.g., avian influenza). Natural calamities and logistical challenges.
- ✓ Small scale producers have limited access to innovative technology that can increase efficiency and quality.
- ✓ Preserving the quality and safety of eggs by keeping them properly refrigerated throughout the supply chain.

- ✓ Inadequate logistics and transportation, which could result in greater costs and possible quality degradation.

Strategies for betterment of meat & egg supply chain:

- ✓ Meat needs to be used effectively and efficiently, and it should be viewed as a valuable commodity rather than a byproduct.

- ✓ A well-functioning supply chain guarantees farmers fair pricing, lower marketing and profit margins, safe and high-quality meat and eggs at competitive rates for consumers, and the effective use of surpluses for economic growth.

- ✓ To guarantee the highest standards of meat safety and quality, implement stringent quality control methods across the whole supply chain.

- ✓ Utilizing IoT, AI, and data analytics technologies to enhance distribution and processing efficiency.

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Chapter 10

Farm Biosecurity Principles for Sustainable Animal Production

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Farm biosecurity is an essential aspect of sustainable animal production, aimed at preventing the introduction and spread of infectious diseases. Effective biosecurity measures protect animal health, enhance productivity, and ensure the safety and quality of farm products. This brief review explores key biosecurity principles, including segregation and containment, risk prioritization, infection pressure reduction, adaptation to farm scale, and community and policy engagement. Segregation involves quarantining new or sick animals and limiting potential contacts to minimize disease transmission. Risk prioritization focuses on identifying high-risk areas and implementing measures such as proper feed storage and pest control. Consistent application of biosecurity measures and managing visitor risks are essential for effective disease control. Infection pressure reduction is achieved through thorough cleaning and disinfection protocols. Adapting biosecurity practices to farm scale ensures practical disease prevention strategies. Community and policy engagement, through education and awareness, local context considerations, and policy support, fosters long-term compliance and adoption of best practices.

By addressing these principles, farmers can create a robust defense system against pathogens, ensuring the sustainability and success of their operations.

Farm biosecurity is considered as a critical aspect of sustainable animal production. Infectious diseases can severely impact animal health and welfare, farm productivity, and the broader agricultural economy at regional and national level (Rich and Perry, 2011). Strong farm biosecurity acts as a protective shield, preventing pathogens from entering, establishing, and spreading within the farm environment. Therefore, understanding and implementing effective biosecurity principles is essential for farmers, managers, veterinarians, and all stakeholders to mitigate these risks (Subasinghe et al., 2023).

Farm biosecurity encompasses measures designed to reduce the risk of infectious agents entering, spreading within, and leaving a farm. These measures include controlling the movement of animals, people, equipment, and vehicles to prevent contamination; ensuring proper sanitation and disinfection protocols; implementing quarantine and isolation procedures for new or sick animals; and maintaining proper vaccination and herd health management practices (Dewulf, and Van Immerseel, 2019). To understand the fundamental farm biosecurity principles crucial for preventing and controlling infectious diseases among farm animals, this review explores key concepts of field epidemiology. These basic concepts include transmission routes of infectious agents, the concept of the basic reproduction number (R_0), risk prioritization for infectious disease spread, and key strategies to interrupt disease transmission cycles.

Importance of farm Biosecurity Measures

Farm biosecurity is indispensable for safeguarding animal health, enhancing productivity, and ensuring the safety and quality of farm products (Dhaka et al., 2023). Some of the important benefits of adoption of farm biosecurity procedures include:

a) **Improving farm productivity**: By minimizing disease outbreaks, biosecurity measures help maintain optimal health conditions for livestock, thereby supporting consistent production levels.

b) **Ensuring farm stability**: Stable farm operations are crucial for sustainable agricultural practices and economic viability, both locally and globally.

c) **Enhancing quality and safety of farm products:** Biosecurity practices contribute to producing safe and high-quality agricultural products, meeting consumer expectations and regulatory standards.

d) **Reducing risk of zoonotic infections:** Preventing animal diseases helps reduce the risk of zoonotic diseases that can transmit from animals to humans.

e) **Improving animal welfare**: Healthy animals lead to improved welfare outcomes, aligning with ethical and regulatory standards.

f) **Decreasing antimicrobial usage and resistance:** Effective biosecurity reduces the need for antimicrobial treatments, thereby mitigating the development of antimicrobial resistance.

Routes of infectious disease(s) transmission:

Infectious diseases in farm animals can be transmitted through several routes, with pathogenic agents exhibiting varying degrees of *infectivity* (the ability to infect a host), *pathogenicity* (the ability to cause disease), *virulence* (the severity of the disease caused), and *stability* (the ability to survive in the environment) (Craft, 2015). The *direct contact* transmission of the pathogen occurs when an infected animal comes into physical contact with a susceptible animal. For examples, many infections like bovine tuberculosis, brucellosis, infectious bovine rhinotracheitis, bovine viral diarrhoea etc. can spread through direct contact with infected animals or contaminated body fluids/secretions. *Aerosol transmission* involves the spread of pathogens through the air via droplets, which is common in respiratory infections like avian influenza, food and mouth disease (FMD), coxiellosis etc (Paton et al., 2018). *Contaminated feed and water* can serve as point sources for introducing pathogens, such as *Salmonella, Campylobacter spp., Leptospira,* or *E. coli,* to healthy animals when ingested. *Fomites, including*

equipment, clothing, and *vehicles*, can carry pathogens from one location to another, highlighting the need for stringent sanitation protocols. *Vectors*, such as insects, ticks or other animals, can act as intermediaries in the transmission of diseases like bluetongue, theileriosis and lumpy skin disease. Pathogens can also be present in bodily excretions, including milk, dung, and other animal secretions, posing a risk of transmission through these mediums. *Reproductive processes* can spread pathogens through abortion or sexual transmission, as seen with brucellosis, coxiellosis, toxoplasmosis etc. Additionally, diseases can be spread iatrogenically through medical procedures or vertically from parent to offspring.

It is important to note that a single pathogen can utilize multiple transmission routes; for example, Foot and Mouth Disease (FMD) can spread both directly through contact and indirectly via contaminated fomites or aerosols (Fig. 1). Understanding these diverse transmission routes is essential for implementing effective biosecurity measures to protect animal health on farms.

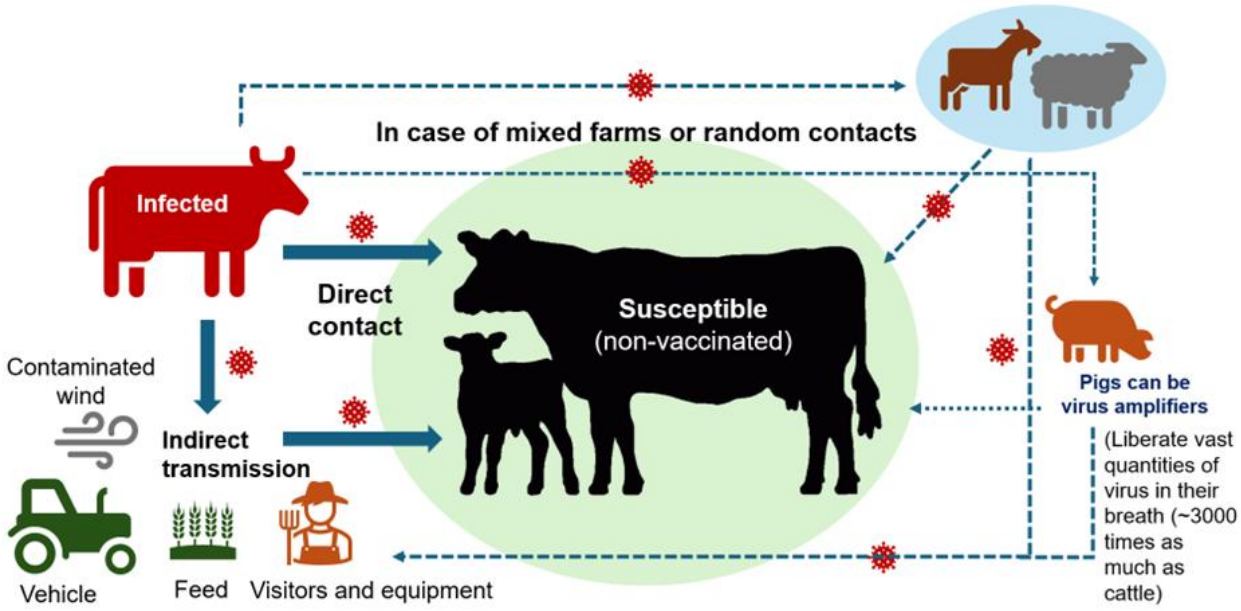

Fig 1: Transmission pathways for foot-and-mouth disease virus in cattle

Assessing the Risk of Infection

To effectively prevent the spread of infectious diseases, it is crucial to assess the relative risk of infection from various farm operations. By identifying and prioritizing these risks, targeted biosecurity measures can be implemented to mitigate the spread of pathogens and protect the health of the farm animal population. Therefore, this allows farmers/farm managers/veterinarians to implement appropriate preventive strategies based on the available resources. The contagiousness of a disease is often represented by the basic reproduction number (R_0), which indicates the number of secondary infections caused by an infected animal in a susceptible population. To understand the mode of transmission of infectious agents is important in assessing and mitigating disease risks. Effective risk assessment depends on identifying the primary transmission routes of the targeted pathogen(s) and evaluating their relative contributions to disease spread within populations. By prioritizing interventions based on the predominant mode of transmission, farmers and veterinary professionals can strategically deploy preventive measures to control and manage outbreaks effectively. For example, FMD is a highly contagious viral disease affecting cloven-hoofed animals. Previous studies have indicated that during the early stages of FMD outbreaks, the basic reproduction number (R_0) ranged from 21 to 88 for cattle (Ster et al., 2012; Hayer et al., 2018). The highest transmission risk occurs through direct contact with infected animals or contaminated inanimate objects. In contrast, Lumpy Skin Disease (LSD) exhibits an R_0 of 15.7 for indirect transmission via vectors, compared to 0.36 for direct transmission (Magori-Cohen et al., 2012). This highlights vectors as the primary transmission route for LSD. Therefore, it is crucial to prioritize infection risk assessments, particularly for endemic diseases, based on their predominant modes of transmission.

Breaking the chain of infection: Key Concepts

Effective farm biosecurity practices focus on disrupting the chain of infection, essentially stopping the pathogen's ability to spread from infected animals to susceptible ones. Understanding key concepts within this framework empowers farmers/farm managers/veterinarians to implement targeted biosecurity measures. Some of the key concepts include understanding and addressing:

a) **Fraction of the host population that is susceptible**:

- **Targeted vaccination programs:** Implementing vaccination programs tailored to specific pathogens is essential, especially for vulnerable groups like calves and milking animals. Vaccinations bolster immunity, reducing the number of susceptible individuals.

- **Optimal nutrition:** Ensuring animals receive proper nutrition strengthens their immune systems, making them less susceptible to infections.

b) **Rate of contacts in the susceptible host population**:

- **Control animal movements**: Limiting interactions at gatherings like livestock fairs (pashu melas) reduces the likelihood of disease transmission. Strict movement controls help prevent the spread of pathogens between herds.

- **Managing introductions**: Carefully monitoring and controlling the introduction of new animals and overseeing visitors, including veterinarians and para-veterinarians, helps mitigate potential risks. Quarantine measures for new or returning animals are crucial.

c) **Probability of infection being transmitted during contact**:

- **Assessing infectiousness**: Understanding the pathogen's ability to spread and its transmission pathways is essential for developing effective biosecurity measures.

- **Implementing barriers**: Utilizing strategies such as quarantine, rigorous cleaning and disinfection (C&D) protocols, isolation of sick animals, and effective fencing can significantly lower the probability of contact-based transmission.

d) **Duration of infectiousness**:

- **Understanding pathogen behaviour**: Factors such as pre-clinical shedding, acute or chronic outcomes, latent infections, and survival outside the host environment (e.g., foot-

and-mouth disease virus surviving for up to six months in slurry) influence disease management strategies. Knowing how long a pathogen remains infectious informs the duration of quarantine and other control measures.

e) **Incursion to detection of new infectious pathogens**:

- **Timely recognition of the outbreak**: Acknowledging the potential lag time between pathogen incursion and detection is critical. During this period, pathogens can spread between farms via animal movements, contaminated vehicles, and personnel. Therefore, rapid detection and response systems are necessary to minimize the spread of new infections

Principles of farm biosecurity

Farm biosecurity is a critical aspect of animal husbandry, designed to prevent the introduction and spread of infectious diseases among farm animals. Some foundational principles of farm biosecurity include segregation and containment, risk prioritization, infection pressure reduction, adaptation to farm scale, and community and policy engagement (Dewulf, and Van Immerseel, 2019). These principles, when effectively applied, create a robust defense system against the introduction and spread of pathogens that threaten animal health and farm productivity.

1. Segregation and containment:

- **Separation of infected and susceptible animals:** Implementing quarantine protocols for newly purchased animals and isolating sick animals reduces the risk of disease spread within the herd. This practice ensures that healthy animals are protected from potential carriers of infectious agents.

- **Limiting potential risky contacts:** Restricting access to farm areas and preventing the sharing of equipment with neighbouring farms minimizes opportunities for disease

transmission. Also, controlling human traffic and equipment usage reduces cross-contamination risks.

2. Risk prioritization:

- **Identifying high-risk areas:** Focusing on high-traffic zones in the farm operations, such as milking parlours and areas where animals congregate, as well as vulnerable resources like water and feed sources, ensures targeted mitigation efforts. Recognizing these high-risk areas allows for the allocation of resources where they are most needed.

- **Implementing effective measures**: Prioritizing practices such as proper feed storage, regular testing of feed and water, and pest control safeguards essential resources against contamination. These measures are crucial in maintaining a clean and safe environment for livestock.

- **Managing visitor risks:** Educating and regulating visitor access to minimize disease introduction from external sources is essential. Considering the cumulative risk posed by frequent visits, it is important to have strict visitor protocols in place.

3. Infection pressure reduction:

- **Cleaning and disinfection:** A proper follow of cleaning and disinfection protocol is important to reduce or eliminate organic and microbial load at farm level. Thoroughly cleaning surfaces to remove organic material before applying appropriate disinfectants is crucial for effectively reducing pathogen load. Regular cleaning schedules and proper disinfection techniques are essential for maintaining a clean and healthy farm environment. Also, using disinfectants specific to targeted pathogens at correct concentrations and contact times optimizes effectiveness.

4. Adaptation to farm scale:

- **Tailoring biosecurity practices:** Adjusting biosecurity protocols based on farm size, production levels, infrastructure, and expansion plans ensures practical and effective disease prevention strategies. Customizing measures to fit the specific needs and capacities of the farm enhances their implementation and success.

5. Community and policy engagement:

- **Education and awareness:** Educating farmers and stakeholders about the benefits of biosecurity fosters long-term compliance and adoption of best practices. Knowledge sharing sessions and training programs can significantly enhance biosecurity awareness.

- **Local context considerations:** Integrating socio-cultural values and community perspectives into biosecurity policies enhances local acceptance and implementation. Tailoring biosecurity measures to fit local practices and beliefs improves their effectiveness.

- **Policy support:** Policymakers and institutions should promote biosecurity through incentives, regulations, and support mechanisms. Providing financial and logistical support encourages farmers to adopt and maintain biosecurity measures, thereby ensuring broader and more effective disease control.

Conclusion

Farm biosecurity acts as a comprehensive shield for animal health and sustainable production. Beyond protecting individual animals, effective biosecurity measures contribute to the overall resilience and sustainability of farming systems. A holistic approach to biosecurity integrates multiple facets, including environmental management, disease prevention strategies, and community involvement. Adopting robust biosecurity practices helps to establish a proactive stance against disease outbreaks, ensuring that farms are well-prepared to handle potential threats. Regular education and training, coupled with clear protocols, enhance the ability of farm

personnel to implement and maintain effective biosecurity measures. Furthermore, biosecurity practices align with broader animal husbandry and public health goals, such as reducing zoonotic risks, reduction in antimicrobial usage and minimizing the environmental impact. By integrating biosecurity into everyday farm operations and decision-making processes, farmers contribute to a healthier animal population, a more stable farm economy, and a safer food supply.

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