E - BOOK

EMERGING TRENDS IN LIVESTOCK NUTRITION FOR HEALTH AND PRODUCTION 2023

Edited by :
Chethan K.P.
Hemanth Gowda, K.
Shahaji Phand
Sushrirekha Das

National Institute of Agricultural Extension Management (MANAGE), Hyderabad, Telangana

Karnataka Veterinary, Animal and Fisheries Sciences University (KVAFSU), Bidar, Karnataka

Veterinary College, Hassan, Karnataka

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This e-book is a compilation of resource text obtained from various subject experts for the Collaborative Online Training Programme of Karnataka Veterinary Animal and Fisheries Sciences University (B), Karnataka & MANAGE, Hyderabad, Telangana on "Emerging trends in Livestock Nutrition for Health and Production" conducted from 29th – 31st May, 2023. This e-book is designed to educate extension workers, students, research scholars, and academicians related to veterinary science and animal husbandry about various technologies in Livestock Nutrition for improvement of Health and Production. 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/editor/authors. Publisher and editor do not give warranty for any error or omissions regarding the materials in this e-book.

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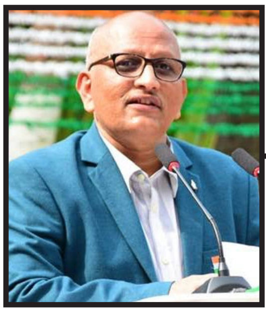

MESSAGE

National Institute of Agricultural Extension Management (MANAGE), Hyderabad is an autonomous organization under the Ministry of Agriculture & Farmers Welfare, Government of India. Agricultural extension to be effective, demands sound technological knowledge to the extension functionaries and therefore MANAGE has focused on training program on technological aspect in collaboration with ICAR institutions and state agriculture/veterinary universities, having expertise and facilities to organize technical training program for extension functionaries of state department.

As India has the largest number of families depending on livestock for livelihood. Which has the highest number of such households. In rural regions, especially among landless labourers and small & marginal farmers, livestock husbandry provides supplemental income for families and creates productive work. The dairy cow, for instance, is seen as a milking machine, and all research and policy efforts are directed towards increasing its milk production, but for dairy farmers, the cow serves a variety of social and economic functions in addition to acting as an asset for landless agricultural labour, a source of "milk money" for milk producers, dung for agricultural land owners, and a source of daily income for resource-poor families..

In order to improve the commercialization of livestock production and provide farmers more financial stability, it is crucial to strengthen industry-farmer ties in a range of livestock products, such as dairy (Amul). This would encourage farmers to pay more attention to the welfare of their animals. It is important to recognise the One Health Approach, including human health, animal health, plants, soil, environmental science, and ecosystem health, which can aid in the sustainability of health and the fight against zoonotic diseases.

This e-book covers an array of subjects, Animal health and Nutrition Extension. I would like to extend my appreciation to, KVAFSU, Bidar & EAAS Centre, MANAGE, Hyderabad for the tremendous effort in compiling this e-book. I also thank the authors, editors, and designers who have contributed to this e-book creation.

Dr. P. Chandra Shekara
(Director General, MANAGE)

FOREWORD

Present challenge in farming especially Animal Husbandry is all about feeding the 7.6 billion world population and more than 9.7 billion by 2050. In this scenario, striving to protect the limited natural resources for current and future food production is not a new endeavour, although the present-day pressures on entire Earth's resources have generated widespread interest in livestock productivity enhancement. Modern farming practices aids tremendously in boosting the food production across the world that too on diminishing cultivable land. Increase in productivity can be augmented with altogether application of scientific knowledge and technological innovations.

Emerging technologies in livestock nutrition offer opportunities to enhance precision, optimize feed efficiency, improve animal health, explore alternative feed sources, promote environmental sustainability and enable data driven decision making. Few of the emerging trends in the field of livestock nutrition are precision nutrition, functional feed ingredients, alternative protein sources, feed additives for gut health, nutritional genomics, sustainable feed production, nutritional strategies for environmental mitigation, digital technologies and data analytics. These latest technologies have the potential to transform livestock production systems making them more efficient, sustainable and productive.

This e-book on the training programme "EMERGING TRENDS IN LIVESTOCK NUTRITION FOR HEALTH AND PRODUCTION" will be useful in enhancing the knowledge in the area and would help in skill development. KVAFSU, Bidar is one of the leading Veterinary University of the country with the mission to cater to Rural oriented and Farmer friendly services for betterment of the farming technologies. Veterinary College, Hassan (HVC) is a fourth constituent veterinary college of KVAFSU, Bidar and it involved in Teaching, Research and Extension services for betterment of the society. I wholeheartedly thank MANAGE and Hassan Veterinary College team in bringing out this e-book on "EMERGING TRENDS IN LIVESTOCK NUTRITION FOR HEALTH AND PRODUCTION" and am sure that it will be a useful for all the registered participants of this Training programme and other stakeholders.

Dr. M. C. Shivakumar
(Dean, Veterinary College, KVAFSU, Hassan)

PREFACE

In India, livestock is an integral part of the agricultural economy and plays a pivotal role in providing livelihood support to about 70-75 million household who own one or the other livestock species. Livestock sector apart from contributing 30% of the GDP of agriculture and allied sector, also plays a pivotal role in employment generation opportunities, asset creation and acts as a best insurance against vagaries of nature like drought and floods. The sustainable development of livestock sector would lead to more inclusive development and socio-economic upliftment of resource poor small and marginal farmers and landless labourers who own the majority of the livestock population. Though India is global leader in milk production, its per-capita availability, demand, quality and safety issues are still a matter of great concern. Livestock feed accounts to about 70% of recurring cost of milk production. Any intervention to achieve sustainability and safer milk standards need to address issues of the feeding and management of livestock. The extension officers of state and central government should travel an extra mile in transferring the knowledge on scientific feeding management to framers to achieve profitable and sustainable livestock production.

This book is designed to provide a comprehensive guide to those who want to run a successful and profitable livestock farming. It covers few of the emerging trends in the field of livestock nutrition viz., precision nutrition, functional feed ingredients, alternative protein sources, feed additives for gut health, nutritional genomics, sustainable feed production, nutritional strategies for environmental mitigation, digital technologies and data analytics. The readers of the book carry a comprehensive understanding of emerging technologies in livestock nutrition which offer opportunities to enhance precision, optimize feed efficiency, improve animal health, explore alternative feed sources, promote environmental sustainability and enable data driven decision making.

This e-book is an outcome of collaborative online training program on "EMERGING TRENDS IN LIVESTOCK NUTRITION FOR HEALTH AND PRODUCTION" conducted from 29th May– 31 st may, 2023. This book will be highly useful and serves as dissemination knowledge on user friendly emerging innovations in livestock nutrition sector suitable for farming community.

The editors express sincere thanks to Prof. K.C. Veeranna, Hon'ble Vice Chancellor, Karnataka Veterinary Animal and Fisheries Sciences University, Bidar, Karnataka, for inspiration and motivation in publishing this e-book. The financial aid provided by MANAGE, Hyderabad for this training program is duly acknowledged. We hope and trust that the valuable inputs provided through this e-book will help to improve the ability of all the stakeholders in Dairy sector to enhance dairy production for welfare of the farming community.

May 2023

Dr. Chethan K.P.
Dr. Hemanth Gowda K.
Dr. Shahaji Phand
Dr. Sushrirekha Das

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Chapter 1

CURRENT STATUS OF FEED AND FODDER RESOURCES AVAILABILITY - INDIAN SCENARIO

Dr. Chethan K. P. and Dr. Hemanth Gowda K.
Associate Professor (I/c)
Department of Livestock Farm Complex
Veterinary College, KVAFSU, Hassan, Karnataka
Email: chethanvet@kvafsu.edu.in

Introduction

India has become the world's most populous country, with 1.42 billion population surpassing china this year 2023. There is a urgent need to increase its food production to feed more people. But simultaneously the purchasing power of the middle class people is also increased due to which demand for animal source protein and quality food has risen. In order meet this demand there is a necessity to increase animal population and productivity with the limited land and water resources.

India is bestowed with large livestock population, but the major problem lies with productivity of these native animals. The livestock population as per 20th census of DAHD, Government of India is 535.78 million in 2019 increase by 4.63% over previous census. Whereas the total poultry population was 851.81 million in 2019 increase by 16.81% over previous census. This increase in livestock population needs increase in feed and fodder resources too. Though there is increase in livestock population the productivity of the animal is poor. The average yield of milk and meat in our animals is 20-60% lower than the global average.

Though there are many constraints in enhancing the productivity of the animals viz., poor genetic resources, tropical environment, small holder system, disease susceptibility etc., the availability of feed and fodder in good quality and quantity throughout the year has been identified as the most important constraint limiting the productivity of the animals in India. Thus information about the quality and quantity of feed and fodder availability, seasonal influence and regional deficit will help in planning and preparedness of the farmers, entrepreneur and policy makers to make appropriate decisions in enhancing feed and fodder resources so as to make livestock husbandry sustainable and profitable.

Livestock resource of India

India ranks first in buffalo (109.85 million), second in cattle (192.49 million) and goat (148.88 million) and third in sheep (74.36 million) population besides good number of other species populations (Table 1) and has second largest poultry industry in the world (DAHD, GOI 2019). this huge livestock population majorly consist of less productive native animals. Whose potential needs to be increased by better feeding and scientific management? Even with such minimal resource India has ranked first in milk production contributing 23% of global milk production and dairy has emerged as the single largest agricultural commodity contributing 5 per cent of the national economy and employing around 8 crore family directly. With increasing demand for livestock products (Table 2) in the future the number of animals also bound to rise.

Table 1. Livestock population in India and World

Livestock	India (Million)	Per cent growth over previous Livestock Census	World (Million)	Per cent of the World
Cattle	192.49	0.83	942.63	14.7
Buffaloe	109.85	1.06	204.0	57.3
Sheep	74.26	14.13	1200.0	5.88
Goat	148.88	10.14	1128.0	13.19
Pig	9.06	-12.03	778.64	0.95
Horse & Ponies	0.34	-45.58	60.0	-
Camel	0.25	-37.05	38.5	-
Total	535.78	4.63	-	-

Source : 20th Livestock Census – 2019, All India Report, Dept. of Animal Husbandry & Dairying, GOI.

Table 2. Predicted per capita demand for animal products in India

	Human Population (Billion)	Per capita Meat availability (Kg/Annum)	Meat Production (MT)	Per capita Egg availability	Egg Production (Billion No.)	Per capita Milk availability (g/d)	Milk Production (MMT)
2021-22	1.42	6.82	8.81	91 no.	121.11	444 .0	221.06
Demand / Projected in 2050	1.7	18.0	18.2	110	-	-	441.04
ICMR Recommandations	-	11.0	-	182.0	-	282.0	-

Source : Basic Animal Husbandry Statistics, MoFAHD, DAHD, GoI, Economic Survey, FAO stat, ICAR Vision 2050, NRC meat Vision 2050.

Importance of feed and fodder resources

The major reasons why feed and fodder resources are needed for livestock rearing are, its deficiency is identified as one of the major constraint in sustaining animal productivity. As more and more farmers are going for adoption of high yielding animals which warrants for increase need of fodder. Because of the increasing human population and simultaneously purchasing power of people is also increased thus, they prefer to consume more meat and dairy products, in such situation there will be a pressure to feed and raise more animals. The traditional method of rearing livestock will gradually change and farmers move towards commercial system of more intensive system of rearing. Livestock sector will bring food security and sustainability in development. hence, the estimates of demand for different feeds will help the policymakers of the country in designing trade strategy to maximize benefits from livestock production. Thus there is a need for fodder and feed resources to meat the increasing demand for animal products in future.

Feed and fodder resources availability in India

The information on the availability of feed resources is not readily available and poorly documented properly in India. The current availability is mostly based on estimates from different scientist following different criteria like animal population, food grain production and products produced (Milk & Meat) therefore availability or deficit varies from one data to other. Thus, The actual feed availability, would be different at the ground level.

Broadly feed resources can be categorized into

1. Dry roughage - straws, stovers and agr-byprodcts
2. Green fodder resources
3. Concentrate feed resources
4. Alternate feed resources

Over the years there is steadily increase in feed resources majorly due increase in productivity per unit of land. The increase is mainly due to increase in crop residues owing to increase in food grain production. Greens availability has more or less remained static while concentrates have increased little majorly due to pressure from poultry sector. The major factors affecting feed and fodder resource availability is the environmental factor. In India availability is seasonal and surplus during rainy season.

Dry roughage is also called as crop residues. Which include straws, stovers and agricultural byproducts? These are the major staple diet of livestock having poor nutritive value thus, fed for maintenance of the animals only. Crop residues provide 54% of total fodder, while range lands provide 18% and only 28% is met from cultivated fodder crops (Hegde, 2010). Though crop residues are produced more, its availability is affected by export and alternate uses viz., paper industry, cardboard making etc. Some of the farmers in Punjab and Haryana state of India crop residues are burnt in the field itself owing to the high cost of harvesting and transportation.

Green Fodder resources include grasses obtained from grass land, alpine, sub alpine and pasture land, community lands, common property resources and waste land, cultivated fodder and forest lands. It is all ways economical to feed dairy animal on green fodder. But the availability of the green fodder round the year is the major constraint. Further, the deficit in green fodder is increasing every year due to urbanization and decreasing land under fodder cultivation which is further aggravating the problem of green fodder deficit (Giridhar *et al.,* 2019). Green fodder availability from different resources is presented in Table 3. Major contribution is from forest land. The scope for utilizing forest land for green fodder cultivation are limited and hence the next highest contribution is from common property resources and other waste land which can be improved, maintained for increasing the green fodder production.

Table 3.Green fodder availability from different resources

Resources	**Gross area (million ha)**	**Percentage**
Forest	69.41	22.70
Permanent pastures/grazing land	10.90	3.60
Cultivable waste land	13.66	4.50
Fallow lands	24.99	8.10
Fallow lands other than current fallo w lands	10.19	3.30
Barren un-cultivable waste lands	19.26	6.30
Total common property resources oth er than forest land	54.01	17.70

Concentrate feed resources

Cereal grains (Maize, wheat, bajra) Oilcakes (GNC, SBM, cotton seed cake, Mustard cake) and Agro-industrial byproducts (Bran from cereal grains0 are the major concentrate feed resources commonly used in livestock industry. The maximum demand for concentrates is for Cattle followed by buffaloe and poultry. Commercially there is well established comped feed industry for Poultry feed, Ruminant feeds & Aqua feeds. The major problem with availability of concentrate feed resource is because of competition between humans and animals for these resource. Other major constraint is the cost of concentrate which is higher and varies with market availability.The coarse cereals account for about half of the total cereals produced and used in livestock feeding. The four major cereals commonly used are Maize (3/4), Barley (15%), Sorghum and pearl millet (11%). In India other millets are produced majorly for Human consumption thus there cost is higher hence difficult to include in livestock ration. Overall there is deficit in availability of all the feed resources in India which is shown in table4.

Table 4. Status of feed and fodder resources in India

Feeds	Available (MT)	Required (MT)	Deficit (%)	Deficit (%)	Demand by 2050
Dry Roughages	433	550	21.3	10.5	1021 (13.2%)
Green Fodder	600	1000	40.0	35.6	631(18.42%)
Concentrate	65	105	38.1	44	-
	(ICAR-NIANP Vision, 2015)			(IGFRI Vision, 2050)	

Table 5. Potential availability of feed resources (000 tons) across the regions of India (2016-19)

Regions	Crop residues	Greens	Concentrates
North	62,460.74	50,510.66	7,266.59
East	79,338.8	1,03,141.3	8,608.15
South	81,778.59	1,14,956.4	11,578.62
West	95,767.56	1,84,307.5	18,890.68
Central	1,44,179.3	1,64,956.7	16,991.69
North east	11,614.53	38,339.4	1284.37
Others	285.75	1,370.6	47.62
India	4,75,426.3	6,57,582.6	64,667.72

Source: Anandan *et al.,* 2022

Current scenario of feeding livestock in India

Majority of the farmers feed whatever is available at no or low cost (Dry roughages). Commonly used staple feed resources are dry roughages which include mainly paddy straw, ragi straw in southern parts of India and In North wheat straw and maize stover which are poor in nutritive value. Farmers usually feed only milk producing animals with concentrates while calf, heifers and dry animals are neglected thus leading to poor productivity in the herd. Feeding mineral mixture to all animals is also rare. Feed processing methods like chopping and soaking of fodder is also are not fully adopted. Green fodder availability is seasonal which warrants adoption of conservation of green fodder which is not universal. They also do not practice balanced animal feeding to the animals due lack of scientific knowledge. They do not have proper plan to establish pasture or community grazing land i.e. zero grazing method which is economical to raise dairy animals.

Constraints to increase feed and fodder resource availability

Limited geographical area, only 2.3% of the total land is available for cultivation. Out of which only 5% of the agriculture land is used for cultivation green fodder - land allotted for fodder crops, pastures and grasslands 12.4 mhs which is 4% of the geographical area. Diminishing forest and natural land due to urbanization and human population. The other constraints include wider geographical diversity, erratic behavior of monsoon and uneven distribution of rainfall. Further the problem is aggravated due to non availability of fresh water required for irrigation facilities and climate change phenomenon leading to decrease in feed and fodder resource availability year by year.

Problems of feed and fodder shortage can be overcome by individual and collective efforts. Which include

1. Use of non competitive unconventional feeds may bridge the gap between supply and demand
2. Use horticultural crop residue as animal feed
3. Conservation of feeds and fodder as hay and silage at community level
4. Increasing the productivity of cultivated fodder crops on the same piece of land
5. Bringing more land under fodder cultivation
6. Establishment of fodder banks at village and district level

7. Fodder seed production-emphasis on seed processing and storage facilities
8. Watershed development programmes.
9. In addition to vertical expansion -hydroponics
10. Newer feed resources
11. Strengthening R&D institutions - forage research.
12. Creation of database on feed and forages
13. Transfer of technology

Some of the individual efforts at farmers door step which can be helpful in the long run are

1. Conversion of fodder into feed blocks which can be transported to needy places
2. Improvement of poor quality roughages by urea ammoniation.
3. Conservation of feeds and fodder as hay and silage
4. Use of chaff cutters for efficient utilization of available fodder resource.
5. Planting multipurpose trees as an alternate feed resources at the bund and fencing areas

Conclusion

Feed and fodder resources available in India with respect livestock population & requirement is inadequate both in quantity and quality. Feed cost is the major recurring cost of livestock production hence, appropriate strategies need to be evolved at national level to improve feed and fodder resource in India for sustainable and profitable livestock production. By judicious utilization of the land and natural resources, we can comprehensibly tackle the upcoming forage and fodder shortage for our livestock in the near future. One of the major strategies is to precise estimate of feed and resource availability at micro or district level & seasons wise is required in the present scenario. Full inventory of the resources needs to be kept and regularly updated so as to fulfill the need for database on feed resource and development of information system. It is possible with the combined efforts from the government, public as well as from the private sectors.

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Chapter 2
Recent Advances in Mineral Supplementation for Better Health and Production

Dr. N.K.S. Gowda

ICAR-National Institute of Animal Nutrition and Physiology, Bangalore 560 030

nksgowda@rediffmail.com

SUMMARY

Micronutrients are required essentially for all biochemical processes in the body. Their requirement in livestock is dependent on level of production, physiological status and feeding systems. Overcoming the deficiency or imbalance of micronutrients improves productive and reproductive efficiency of livestock. Micronutrients have a pivotal role as antioxidants and stress alleviators. Region based feed resource, cataloguing for mineral content will help in strategic supplementation of limiting minerals in different regions is a practical and cost-effective approach. Mineral utilization in gut depends on several factors like chemical form, accompanying feed and anti-nutritional factors. Strategies like balancing the proportion of minerals in diet, use of better bioavailable mineral salts and sources (chelates/organic/nano/encapsulated) and enzyme supplementation to degrade anti-nutritional factors like phytate will improve mineral utilization and reduce the excretion in manure. Biochemical and molecular markers for assessing the mineral status in animals will help in precise confirmation and type of deficiency. Study on newer minerals like chromium, boron and vanadium has deciphered their role as occasionally important elements.

INTRODUCTION

Micronutrients are as essential as energy and protein, but general negligence occurs primarily because they are required in small quantities, making them less significant in comparison to macronutrients. However, their role in regulating enzyme / hormones involved in metabolism, production and health, cannot be under rated. Deficiency of minerals and vitamins frequently in diets consisting of common feed ingredients, and hence these need to be provided in a supplemental form. The term ‘requirement’ for minerals is only a guideline as many conditions like antagonism / synergism and productivity level govern the requirement. Besides, the extent of bioavailability of individual mineral influences the dietary requirement. Thus specific mineral deficiency or toxicity problem become area or feed specific. Mineral resources are finite in nature and hence to be used with caution. Excess excretion in manure will leach out to water bodies and promote algal growth and eutrophication. Efforts should aim at improving the utilization of minerals in body, optimizing the dietary level and precision in supplementation.

SOIL-PLANT-MINERAL-ANIMAL RELATIONSHIP

Several factors regulate the transfer of minerals from soils to plants and from plants to animals. Soil characteristics (pH, moisture), the type of plant (green fodder, legume and mature straws etc.), the physiological status of the animal (growing, pregnant, lactating) and the accompanying feed, all of these individually and/or collectively contribute to the mineral uptake and utilization. The availability of minerals in soil depends upon their effective concentration in soil solution and is also influenced by soil acidity, moisture, temperature, plant variety, fertilization, organic matter and microbial activity of soil. With the passage of green revolution, deficiency of micronutrients was observed widely in several Indian soils and crops. While soil-plant-animal relationship may point towards area problem of specific mineral deficiency, the relationship is not linear in many situations. However, there is a good response to zinc application to Zn deficient soils in terms of increase in Zn content in green fodder and plasma Zn level in sheep fed such green fodder.

Plant varieties growing on the same soil under the same environmental conditions show marked differences in mineral uptake. Legumes are superior in Ca and Mg uptake from soil compared to the grasses. In contrast, grasses tend to be higher in Mn and Mo than legumes when grown on the same soil. Most of the trace mineral concentration was higher in pasture legume species than other grasses. Some of the crop residues contain excess of silica, oxalate and tannins which will interfere in the utilization of other minerals / nutrients. Plant requirement for certain minerals (Mn, Zn, K) exceed the animal requirements and certain minerals are required at higher levels by animals like Sodium (Na), Chloride (Cl), Iodine (I) and Selenium (Se). Similarly, the concentration of trace elements such as Cu, Co and Mo in forage crops is usually lower than the requirements for ruminants and pigs and hence, these elements are added as mineral salts.

MICRONUTRIENTS AND REPRODUCTION

Deficiency / excess of micronutrient intake may adversely affect the various stages of the reproductive events leading to delayed puberty, reduced ovulation, lower conception rates, and long post-partum anoestrus. The micronutrient-mediated effects act either directly on the gonads / reproductive organs or indirectly via the hypophyseal-pituitary-gonadal axis. The role of some specific micronutrients is presented in Table 1. Supplementation of micronutrients is very much essential to support reproductive functions. Inspite of adequate protein / energy nutrition, deficiency of micronutrients can alter the cellular functions leading to low fertility. The supplementation of minerals based on the feeding practice and blood mineral status is a more practical and cost-effective approach. As per the research data of ICAR-NIANP, majority (>50%) of the repeat breeders were deficient in Zn and Mg and the silent heat animals were deficient in Ca, P, Mg and Zn. The majority of the delayed pubertal animals were deficient in P, Mg and Zn. The plasma minerals such as Ca and Zn were significantly lower in reproductively problematic animals as compared to normal animals.

Table 1. Functions of micronutrients on reproduction

Nutrients	Reproductive function
Calcium	Uterine involution, maintain uterine muscle tone
Phosphorus	Maintenance of oestrus cycle
Zinc	Wear and tear and of uterine epithelium, Maintenance of semen quality
Copper	Zinc – reproductive hormones – Progesterone and oestrodiol
Manganese	Synthesis of steroid, oestrogen, progesterone and testosterone
Iodine	Reduces fertility in male and female, Maintaining semen quality
Selenium	Role as antioxidant, Maintain health of uterine tissue, ovary
Cobalt	Attain puberty, uterine involution, Maintain early pregnancy
Boron	Increased sperm output, sperm motility, Enhanced immune and antioxidant capacity, potentiates estrogen activity
Chromium	Follicular maturation and LH secretion (?), secretion of pregnancy specific proteins in uterus, trivalent form of Cr is beneficial
Vitamin A	Tissue regeneration, anti-oxidant, steroidogenesis
Vitamin D	Ca/ P homeostacis, foetal growth
Vitamin E / Se	Anti – Oxidant activity and gonadal activity

OXIDATIVE STRESS AND MICRONUTRIENTS

Heat stress impairs animal performance and it has been implicated in promoting oxidative stress (OS) either through excessive reactive oxygen species(ROS) production or decreased antioxidant defences. An impairment of the antioxidant systems can often be the consequence of damage from ROS through deficiencies in the antioxidant vitamins and minerals and therefore a decrease in antioxidant status can be the direct consequence of an increase in ROS. In dairy cows, oxidative stress has a negative impact on immune and reproductive functions. A deficiency in zinc, manganese, copper or selenium can contribute to tissue oxidative damage. These are the active components of well-known antioxidant enzymes such as superoxide dismutase (SOD) and Glutathione peroxidase (GSH-Px). Moreover, zinc is also associated with metallothionein (MT), which can act as an antioxidant. Research has shown that zinc can act as specific antioxidant protecting macromolecules against the negative effects of iron-induced oxidative stress. It was shown in peri-parturient dairy cows that zinc is an effective antioxidant when iron is fed in excessive amounts. Vitamin E was only effective as an antioxidant at low iron dietary levels, but ineffective at high levels. In particular, the glutathione peroxidases family of anti-oxidative enzymes, containing selenium incorporated within an amino acid (organic form), plays a major role in maintaining the anti-oxidative balance, protecting the cells from damages. Supplementation of sheep diets with supranutritional (greater than normally recommended) levels of vitamin E and Se ameliorates the negative effects of heat stress on feed intake, respiratory physiology, rectal temperature, acid base balance and OS suggesting that dietary vitamin E and Se not only act as antioxidants, but also influence body homeostasis (namely thermoregulation) when administered at supranutritional levels.

Table 2. Antioxidant enzymes and minerals

Enzyme protein	Related Mineral	Function
SOD (cytosol)	Cu, Zn, B	Convert superoxide ions to peroxides
SOD (mitochondria)	Mn, Zn	Convert superoxide ions to peroxides
Ceruloplasmin (liver/ blood)	Cu	Prevents Cu from participating in oxidation reaction
Ferritin (liver/ blood)	Fe	Prevents Fe from participating in oxidation reaction
Glutathione peroxidase (cytosol)	Se	Convert peroxide to water
Glutathione (cytosol)	Sulfur	Neutralizes free radicals
Catalase (cytosol)	Fe	Convert peroxide to water

MICRONUTRIENT SUPPLEMENTATION

Performance of livestock in the tropics is mainly governed by the quality and quantity of nutrients provided in the diet. In most of the developed countries, the principal means by which cattle producers try to meet the requirement is through use of free - choice dietary minerals. This is neither practical nor cost effective in developing countries where the livestock are fed on crop residues and concentrate by-products. Where compounded concentrate diets are not fed, it is necessary to rely on both indirect and direct methods of providing minerals.

Enrichment of soil

In the indirect approach, soil treatment of deficient minerals would make these elements accumulate in plants. For instance soil treatment of cobalt and selenium will improve their concentration in plants without having any effect on plant yield. This effect may be neutralized in high alkaline or calcareous soils, as the uptake of cobalt by plants in such soils would be affected. Copper application makes it more available to plants in soils low in molybdenum content, but will not be effective when soils contain high molybdenum. High application of NPK fertilizers reduces the calcium, magnesium and sodium availability to plants. So the approach to enrich the soil through micronutrient supplementation may not be very cost effective and also may not yield the desired results due to the variation in soil profile in different zones. Trace element intakes that can be improved by fertilization include selenium, cobalt, copper, zinc, boron, and possibly nickel.

Mineral biofortification of plants

One sustainable agricultural approach to reducing the mineral deficiencies in livestock animals is to enrich major staple food crops (rice, wheat, maize) with minerals through plant breeding strategies. Biofortification of plants with minerals may be a promising and cost-effective intervention. The idea is to breed food or fodder crops for higher micronutrient content through crossbreeding or genetic engineering.

Direct methods of mineral supplementation

In tropics, the livestock farmers provide some quantity of cakes, bran, rice polish and husk as concentrate supplement to productive animals. Unproductive animals are generally allowed to graze on left over fields. Some quantities of greens are offered during rainy season which are grown on the bunds in the field. The animals do not receive any mineral supplement and even salt is not being fed. The possible reasons would be the high cost involved and lack of awareness. The direct approach of supplementing micronutrients in the diet of cattle depending on the severity of deficiency may be a more practical method. The most efficient method of providing trace minerals is through mineral mixture mixed with concentrate feed ingredients. This assures an adequate intake of mineral elements by each animal. This procedure represents an ideal system for providing supplemental minerals but it cannot be used with grazing cattle, which receive little concentrates and depend on forages or where concentrates are not fed. Use of mineral supplements in the form of mineral mixture or mineral licks and premixes are most commonly used methods. Supplementation can also be achieved through feeding compound feeds, oral drenching or dosing or by administering slow releasing mineral boluses which are retained in the gut and in the form of injectable preparations.

Supplementation of area-specific mineral mixture

Providing area-specific mineral mixture based on the deficiency of minerals in different agro-climatic zones is most appropriate and cost effective method of mineral supplementation. The traditional mineral mixture could sometimes lead to unfavourable effect, as some of the minerals may be available in excess than requirements affecting utilization of other minerals. For example, excess of calcium disturbing the Ca-P ratio, excess of selenium affecting sulphur utilization, excess of molybdenium and sulphur reducing copper absorption and excess of iron disturbing copper and zinc metabolism. More practical method is of supplementing only the most deficient minerals through area specific mineral mixture by assessing the mineral content in soil, feeds and fodders and in animals in different agro-climatic zones. This approach has been found to improve the reproductive efficiency in crossbred cattle under field conditions and this technology has been a great success.

Local feed resources

Other cost effective method of mineral supplementation is to provide feed and plant sources rich in the specific micronutrient, which are commonly being fed / grown in that particular region. For example cakes, brans & rice polish are rich sources of phosphorus. Similarly top feeds / tree leaves and legumes are good sources of calcium, copper and zinc. In general, legume fodders, cultivated green fodders and tree leaves are good sources of Ca, Fe, Zn, Cu, Co and Mn and oil cakes and bran are good sources of P, Zn, Cu and Mn.

IMPROVING BIOAVAILABILITY

Due to mineral interaction in gut, their bioavailability, particularly trace elements gets limited. Efforts have been made to improve the bioavailability of trace minerals and are quite successful. Organic and chelated minerals, nano minerals, trace minerals-enriched yeast have gained popularity because of a number of perceived benefits to their use over the inorganic salts. As a result, the development of organic forms of trace minerals, such as minerals chelated with amino acids, nano form of trace minerals, and trace minerals-enriched yeast are an alternative to minimize the risk of mineral antagonism and enhance absorption efficiency.

Chelates and Organo-Mineral complexes

A chelate is best described as a metal complex in which the metal atom is held in the complex through more than one point of attachment to a nonmetal entity referred to as ligand (chelating agent). A ligand is a molecule containing an atom which has a lone pair of electrons. In the process of chelation, the ligand acts as chelating agent and encircles the metal atom to form a heterocyclic ring structure. That is, the metal atom is bonded to the ligand through donor atoms such as the oxygen of the carboxyl group, nitrogen or sulfur of the amino acid or peptide. Ligands that contain only one donor atom are termed as "mondentate" ligands and those contain two or more donor atoms capable of bonding to metal ion are termed as bi, tri or tetradentate ligands. When such ligands bond to a metal ion via two or more donor atoms, the complex formed contains one or more heterocyclic rings and they are called "chelates". In theory, the introduction of chelated minerals will increase absorption and utilization of the mineral because of more favourable binding or stability constant. The mineral is protected from physiochemical factors or from negative interactions with dietary components such as phytate. Thus, the mineral chelate/complex is absorbed intact through the intestinal mucosa, traversing the mucosal cell membrane into the plasma. Minerals using either amino acid or peptide uptake mechanism would therefore be expected to be absorbed and circulated to target tissues very efficiently, hence, highly bioavailable. There are various categories of organic trace minerals as defined by Association of American Feed Control officials.

Metal (specific amino acid) Complexes: This is the product resulting from complexing a soluble metal salt with a specific amino acid. For instance, one of the most common metal complexes is zinc methionine which is produced by combining zinc sulfate with the amino acid methionine. Other common metal (specific amino acid) complexes include copper lysine and manganese methionine. When considered with the consistency and stability, these complexes are probably the most effectively and efficiently absorbed of all the complexes.

Metal Amino Acid Complex: It is the product, which is characterized by a metal atom (zinc for instance) complexed with several single amino acids. Each individual molecule is still one metal ion and one amino acid but have a variety of amino acids in the blend. For instance for a zinc complex in this category, the blend would include zinc methionine, zinc lysine, zinc leucine, zinc cystine, etc. with each molecule being specific but the whole product being a blend of these complexes.

Metal proteinates result from the chelation of a soluble mineral salt with amino acids and/or hydrolyzed protein. The final product may contain single amino acids, dipeptides, tripeptides or other protein derivatives. Metal proteinates tend to be less expensive than other organic mineral complexes.

Metal amino acid chelates are formed from the reaction of a metal ion from a soluble metal salt with amino acids having one mole of metal to one, two or three (preferably two) moles of amino acids to form coordinate-covalent bonds. Somewhat similar to the proteinates in variability, they are normally a smaller and somewhat more stable molecule.

Metal polysaccharide complexes result from complexing a soluble salt with a polysaccharide (carbohydrate) solution declared as an ingredient of the specific metal complex e.g. copper polysaccharide complex. These are larger molecules based on chains of simple sugars that are known to be highly soluble in the digestive tract.

Metal propionates result from the combining of soluble metals with soluble organic acids such as propionic acid. The resultant products are highly soluble and generally disassociate in solution.

Yeast Derivative Complexes: One other source of organic trace elements that is showing promise are those integrated into a yeast cell for feeding as a trace mineral-enriched yeast. The most common of these at this time is selenium yeast with the selenium found largely to be complexed with a methionine molecule (selenomethionine).

Economic and environmental considerations

Dietary requirement of minerals will be greatly reduced by the addition of organic minerals to animal diets, but cost-to-benefit ratio need to be considered. More often in comparative studies using organic and inorganic sources, the cost is calculated as one to one basis. But one should keep in mind that if inorganic elements are 40-50% bioavailable, chelated minerals are 2-2.5 times more bioavailable. Due environmental concerns, it becomes necessary to lower supplemental trace mineral levels and adjust proportions of inorganic with organic in order to maintain optimum performance, profitability and environmental stability.

Similar to trace mineral bioavailability, issue of phosphorus (P) in monogastrics is a concern. A multifaceted approach integrating nutrition, genetics, manure management and innovative soil and crop management practices is required to lower faecal- P excretion. Reducing dietary P inputs through judicious use of feedstuffs and improving gut utilization of P to reduce faecal-P excretion. Desired dietary level of P in ruminant and monogastric animals and improving gut bioavailability using better bioavailable inorganic sources and balancing of different micronutrients and phytase enzyme supplementation are few of the remedies. Improved manure management from animal husbandry to effectively recycle nutrients including P, needs further research efforts. Efforts towards nutrient recapture from manure and other wastes like to egg shell requires specific attention.

Nano Minerals

Nanoparticles present a higher surface volume with decreasing size of the particle. Nanoparticles exhibit unique properties in terms of chemical, physical, photo-electrochemical and electronic properties when compared to their respective bulk materials. All these applications require customized synthesis methods for specific applications. Nanotechnology holds promise for medication and nutrition because materials at the nanometer dimension exhibit novel properties different from those of both isolated atom and bulk material. Nano-structured metal particles can be synthesized either by the “top down method”, *i.e.*, by the mechanical grinding of bulk metals (physical method), or via “bottom-up method” which rely on the wet chemical reduction of metal salts (nucleation and growth of metallic atoms). Recently, integration of biological components in the formation of nano sized particles leading to the complete green synthesis of nanoparticles has emerged as novel method and gaining more importance among researchers. For the synthesis of nano-particulate metal colloids, a large variety of stabilizers, e.g. donor ligands, polymers and surfactants are used to control the growth of the initially formed nano-clusters and to prevent them from agglomeration. Supplementing Nano Zn has been reported to reduce somatic cell count (SCC) in subclinical mastitis cows and increased milk production than other conventional ZnO sources. ZnO NP has been reported to enhance growth performance, improve the feed utility and provides good economical profit in weanling piglets and poultry. Many researchers have pointed out the antimicrobial action of metal oxide NPs. ZnO NPs have bactericidal effects on both Gram-positive and Gram-negative bacteria and it has the potential in reducing bacterial growth for practical applications.

Mineral enriched yeast

Other sources of organic trace elements that show promise are mineral enriched yeast. Presently the most common is selenium yeast with selenium complexed with a methionine molecule (selenomethionine). Chromium enriched yeast also has gained popularity for improving animal production due to improvement in immunity, reduction in clinical mastitis and improved the reproductive efficiency.

Encapsulation of trace minerals

To facilitate improved micro-nutrient stability and bio-availability, efficient delivery systems are needed for their stability and bio-availability to stabilize the micronutrient within food, but release in a bioactive form even after consumption. Microencapsulated compound of Zn-chlorophyll derivatives extracted from pandan leaf by using spray dried method has been developed. Three wall materials like gum arabic, maltodextrin and osa-modified starch has been studied for encapsulation. A novel method for encapsulated zinc using Zinc sulphate heptahydrate as core material and maltodextrin, HI-CAP® 100 and whey protein isolate as wall materials was microencapsulated by spray-drying using . Spray-drying conditions were optimised using Taguchi orthogonal array design with encapsulation efficiency and bulk density as responses. Fortification of milk with zinc microcapsules did not affect its inherent organoleptic qualities. Supplementation of different forms of zinc within the biological limits resulted in similar production performance, plasma zinc concentration and apparent crude protein digestibility, However, supplementation of encapsulated zinc at lower concentration has resulted in higher zinc apparent ileal digestbility and could exhibit similar response as that of lower levels of organic zinc feeding to broiler chickens.

BIOMARKERS FOR MINERAL STATUS ASSESSMENT

Sub-clinical or marginal deficiency of minerals are very widespread and are likely to be more economic significance than are easily recognized cases. Parameters like growth rate, tissue and physiological fluid concentration, enzyme concentration and activity, chemical balance and mobilizable stores are some of the indeces for assessing mineral status. Blood and its specific nutrient concentrations provide useful but frequently inadequate index. Specific biochemical and physiological measurements including enzyme activity, such as glutathione peroxidase, selenoprotein, selenoprotein mRNA levels for Se, acute phase protein (Ceruloplasmin), Cu/Zn-superoxide Dismutase (Cu/Zn-SOD), Cu chaperone CCS and other cupro-enzymes for Cu, hair and cells concentrations, alkaline phosphatase and Zn-binding protein (metallothionein), Zn-metaloenzymes, metallothionein mRNA for Zn, Cu/Zn-superoxide dismutase for Cu and Zn, urinary iodine, blood concentration of thyroid stimulating hormone and thyroglobulin for I status provide useful endpoints for assessing the mineral status of animals. The potential for identifying suitable biomarkers using high-throughput technologies such as transcriptomics and proteomics are essentially needed if search for mineral biomarkers are to be successful.

NEWER TRACE ELEMENTS

There are few trace elements which are present in very low concentrations and their beneficial functions have been studied. Chromium (Cr) is known to influence glucose utilization and is termed as glucose tolerance factor. Practical diets of livestock appear to contain enough Cr to meet the requirement inspite of its low availability from feed stuffs. Supplementation of Cr as Cr-picolinate to ruminants has increased the feed efficiency. Boron (B) supplementation has shown to improve bone strength, increased Ca, Mg retention and semen quality. Boron appears to have Vitamin D sparing action. Silicon (Si) is essential for growth and bone development in rats and chicks and believed to be associated with glycosamine and collagen synthesis. Induced Vanadium (V) deficiency in rats and chicks resulted in reduced feather growth, iron metabolism and impaired bone development. Further detailed research is required to confirm the essentiality and supplementary value of these newer trace elements.

CONCLUSIONS

Minerals play a significant role in production and reproduction either singly or in combination. Overcoming the deficiency or imbalance of the trace minerals improves the productive efficiency of livestock to great extent. Hence minerals are to be considered in tropical feeding system not in isolation but as a part of total nutrient management system. In India, where land availability for grazing or fodder cultivation is less and type of cultivar(grains, legumes, oil seeds) is designed mostly for human consumption, only the by-products are available to animals. Hence the emphasis should be on ways of mineral supplementation, cost-effectively based on prevailing livestock farming system and available resources. Three forms of mineral supplements can be practically adopted. 1. General purpose, productivity supporting, inorganic mineral compounds 2. Special purpose (high phosphorus, high calcium, high zinc), which are area specific formulated depending upon valid area survey results. 3. Organic ligand bound specific supplements (chelates, proteinates, amino acid complexes) for feeding under stressful / deficient conditions. Research on nano and encapsulated minerals is still in its initial stages.

Chapter 3

Recent developments in fodder production and conservation

Dr. K. Giridhar,
ICAR-National Institute of Animal Nutrition and Physiology, Bangalore 560 030
girikanu@gmail.com

Introduction

Green fodder is most essential for sustainable and economical livestock production. The profitability of livestock rearing is dependent on the sources of feed and fodder, as 65-70% of the total cost is attributed to feeding. Any saving in feeding cost would directly contribute to increase in profitability. By using good quality forage, particularly leguminous fodder, feeding of concentrate can be reduced significantly. The area under fodder crops is declining in various states and is adding further to the problem of deficit of green fodder availability. There is an urgent need to improve the productivity of existing acreage under fodder crops by improving cropping intensity. For ensuring continuous supply of green fodder throughout the year, it is essential to have proper cropping plan with different fodder crops in an overlapping system to obtain economically viable maximum forage yield. If the supplemental irrigation facilities are available, selection of high yielding perennial grass like hybrid napier bajra or multicut jowar as the main component of the system is ideal to ensure continuous supply of green fodder. Adoption of mulching can greatly minimize the evaporation losses in the dry lands. Similarly, addition of liberal quantities of organic manure at regular intervals will improve the water holding capacity and fertility of the soil. Similarly, providing supplemental irrigation after the cessation of rains will ensure better biomass yields. In view of the vagaries of monsoon, it is essential to adopt water harvesting practices to store the rain water during the monsoon season for providing irrigation during the prolonged dry spells or post-rainy season. Forage crops like Jowar, bajra and Rhodes grass can tolerate low rainfall conditions better. The new improved varieties of Jowar like Co FS-29 and 31 are fairly tolerant to drought and can also withstand temporary waterlogging conditions well. These varieties can give at least two to three cuts even in the regions with less annual rainfall (750 mm), if sown in early part of June and can be easily maintained for over three years, without the need for sowing each season. Fresh jowar seeds have dormancy for a period of 45-60 days and hence, should be used for sowing only after 60 days. During the dry season, jowar crop remains stunted in growth and will put forth new growth when enough soil moisture is available. In case of pearl millet, Baif bajra-1 variety performs well in dry lands and gives 2 to 3 cuts for green fodder. The other merit is that it is a dual purpose variety and so, after taking the first cut for fodder at about 40 days, regrowth is allowed to provide 10 to 12 quintals of grain along with 30 quintals of stover per hectare.

Use of efficient irrigation system like micro sprinklers or drip will greatly minimize the water requirements and ensure best utilization of limited water. In dry land areas, relying on crop production alone is risky due to the vagaries of monsoon. A tree-cum-crop farming system is appropriate for such situations. Alley cropping, a version of agro-forestry system, can meet the multiple requirements like food, fodder and fertilizer. Alley cropping is a system in which food crops are grown in alleys formed by hedge rows of trees/shrubs. The hedge rows are cut back at planting and kept pruned during cropping to prevent shading and competing with the food crops grown in the inter row spaces. Subabul or Sesbania are ideal as the hedge rows. Drought tolerant dual purpose grain crops like Sorghum or Bajra can be selected for cultivation in the alleys during the monsoon season.

A few important details like seed rate, spacing, and green fodder yield for major fodder crops are given below.

Forage crop & important varieties	**Seed rate (kg/ha) and spacing**	**Harvesting time (days after sowing)**	**Green fodder yield (q/ha)**
Jowar - Pusa chari, SSG 59-3,CSH 24 MF,PC- 9 and 23, CoFS -29 and CoFS -31	40 kg for normal varieties and 10 kg for multi-cut varieties 30 x 15 cm	80-90 (late maturing varieties) 65-75 (early varieties)	300-400 (single cut) 1350 to 1600 in five cuts per year for perennial varieties like COFS-29 & 31.
Maize - African tall, APFM-8, J-1006 and VL-54 Composites like Vijay, Moti and Jawahar	40 kg 30 x 15 cm	75-90 (late) 60-75 (early)	350-550
Bajra - Giant bajra, BAIF Bajra-1, AVKB-19, Deenabandhu & Co-8	10 kg 25 x 10 cm	60-75	250-320
Cowpea - BL-2, UPC-4200,5286 and 5287, Shweta, Co-5 and CoFC-8, MFC 09-1 and 3	25 kg 30 x 15 cm	60-80	150-200

Lucerne - Anand-2 and 3, Type-9, RL-88 and Co-1	15 kg 25 cm-solid sowing	First cut 75 to 90 days after sowing. Subsequent cuts at about 30 days interval.	700-750
Napier-bajra hybrid - Sampoorna, DNH-15,IGFRI-6,7 and 10, RBN-1, PBN-83, APBN-1, Co- 3, 4 and 5, BH-18 & PNB-233	40,000 root slips or stem cuttings 50 x 50 cm	First cut at 65 to 75 days. Subsequent cuts at about 40 days interval.	1600-2000 in 6 to 7 cuts per year
Guinea grass - Riversdale, Macuenni, Hamil, PGG-19 and 101, Co-2 and 3, BG-1 and 2, DGG-3	Seeds @ 2.5 kg/ha **or** 66,000 root slips at 50 x 30 cm spacing	First cut 75 days. Subsequent cuts at about 45 days interval.	1100-1500 in 5 to 6 cuts per year (Shade tolerant crop and hence, suitable for orchards and agro-forestry systems)

To overcome the shortage of green fodder, hydroponic units for production of green fodder are being installed in different parts of the country in recent years. Majority of these units run on electricity and need continuous and reliable power supply to control the temperature as well as humidity. The other major limitations are high cost of production (capital, depreciation and running costs), handling of very high moisture feed and risk of mould growth. To overcome these problems, ICAR-NIANP, Bangalore developed a simple and cost-effective method of producing mold-free grain sprouts on local crop residue bedding with minimum water usage.

Methodology of sprouts production

Hydroponics refers to the technique of growing plants in water or nutrient solution, without the usage of soil as medium of growth. The new method is a modified hydroponic way and does not require electricity as, manual or battery operated sprayer is used for spraying water. Good quality grains like maize/wheat/horse gram need to be cleaned with water and soaked in a bucket of water for a day. Later, these wet grains are removed from the bucket and kept tightly packed in wet cloth for about 36 hours in a dark place to ensure rapid germination. Germinated grains are taken out of the cloth and placed in 4% vinegar solution for about 30 minutes to prevent the mold growth. Later, these grains are transferred on to quarter inch thick straw beds made with any locally available chaffed straw of rice, jowar, wheat, finger millet, bajra etc. These trays with fine holes at the bottom to drain excess water are housed in a shelf made with locally available materials like bamboo or Eucalyptus poles for corner support, and split bamboo sticks for racks. The shelf with 4 racks secured on all sides with PVC coated galvanized iron net costs Rs.3, 000. The iron net will prevent eating of grains by squirrels, rodents, birds etc. Germinated grains are placed on straw beds and a sprayer is used to apply water 3 to 4 times a day in places with moderate climate, and up to 6 times in hot and dry places. The grains are grown in sun light for about 6 days till the seedlings are 4 to 5 inches tall. The thick mat of grain sprouts along with straw bed is taken out and fed to the livestock. About 8 liters of water is needed to obtain over 4 kg of sprouts from 1 kg of maize grains. Tests done by Krishi Vigyan Kendras in 4 states have shown that by feeding 4 to 5 kg of sprouts per day during green fodder scarcity periods, the milk yield improved by 0.8 to 1.2 liters per day per cow. In the field trials conducted by ICAR-NIANP in the lean months of 2021 and 2022, the combined feeding of 3 kg of legume (cowpea or horsegram) sprouts + one kg of maize sprouts per day improved milk yield by about 1.3 liters per day. Milk quality and animal health also improved due to better feeding. It costs just Rs.5 to produce one kg maize sprouts with this technology. NIANP standardized the technology for producing grain sprouts in the hydroponic units run on electric power to a startup company, M/s Hydro greens pvt ltd, Bangalore. To ensure uninterrupted operation even in the remote villages solar powered unit was designed by that company at an additional cost of Rs.12, 000. The new design has a solar panel to provide 40 watts for running the diaphragm pump to spray the water at set intervals, using the control panel.

Fodder trees

Providing top feeds from the trees will help to bridge the deficit of green fodder. In dry regions, their utility is much more pronounced. Trees like Sesbania, Subabul, Gliricidia, Melia etc. perform well even in dry lands. The normal farmers' practice of lopping only the side branches and allowing the uninterrupted growth of main stem reduces the yield. Instead, main stem is to be pruned to a height of 5 feet when the trunks of fodder trees are about 1.5 inches in diameter. Normally, it takes about 8 to 10 months to reach this stage. After the first lopping, subsequent harvests can be done at an interval of around 60 days.

Conservation of fodder

Conserving the excess fodder produced during plush season is essential to ensure supply of green fodder during the lean periods.

Hay: The primary purpose of hay making is to reduce the water content of the green herbage so that it can be stored for long, without undergoing spoilage like fermentation, and mould development. The green fodder harvested at pre-flowering to flowering stage is dried to reduce the moisture level to about 16 %. Quality hay can be produced from fodder crops that have more proportion of leaves and thin stems. Good hay should be leafy and greenish in colour.

Silage: It is preservation of green fodder in its original form through anaerobic fermentation. Oxygen-free environment and low pH are essential to preserve the quality during storage. Fodders which have thick stem and more sugar content like maize and sorghum are well suited for silage making. The fresh fodder harvested during grain filling stage with desired moisture content of 65-70% is chaffed. Adequate compaction is required while filling the chaffed fodder to remove air for ensuring anaerobic fermentation. The silo should be covered securely with plastic sheet and old tyres can be placed on the top to ensure proper compression. Care must be taken to prevent the entry of water and air. The silage will be ready in about 30 days. Good silage will have greenish yellow colour with a vinegar odour and a pH of 4.2 or less. Farmers needing large quantities can construct large stone or cement pits. Small holders can prepare silage in 100 kg poly bags or 210 liter capacity plastic drums. Drum silage method was tested in 10 adopted villages of under the World Bank aided National Agricultural Innovation Project (NAIP) livelihood project in Chitradurga district of Karnataka and it gave encouraging results. Feeding of 4 to 5 kg of silage (in addition to dry fodder and concentrate) during the summer months improved milk yield by about one liter per day. The main problem with polybags is that they are prone to the damage by rodents and even a small hole will spoil the silage stored and make these bags unfit for using again. The drums are most durable and easy to handle. About 100 kg of silage can be made in 210 liter capacity drums.

Conclusion

In the past decade, several technologies in the form of high yielding varieties, crop production as well as protection technologies have been developed. Several institutes, including KVKs and private companies are producing the seeds of all popular fodder varieties at several locations across the country, ensuring better availability of the seeds and planting material.

Complete economic benefits of forage crops have not been fully realized. Farmers usually allot marginal land to the fodder cultivation with minimum or no input. The trend must change and growing quality fodder with higher productivity should become an integral component of livestock farming. Addition of sufficient organic manure to the soil, integrated nutrient management and providing supplemental irrigation will help in producing adequate green fodder and reduce the dependence on the costly concentrate feeds.

Chapter 4
COMPREHENSIVE NUTRITIONAL MANAGEMENT STRATEGIES TO PREVENT METABOLIC OR PRODUCTION DISORDERS IN CATTLE: A PRACTICAL APPROACH

***Dr. Hemanth Gowda K., Dr. Chethan K.P. and Dr. Ramesh D.**
*Assistant Professor
Department of Veterinary Physiology & Biochemistry
Veterinary College, KVAFSU, Hassan, Karnataka
Email: hemannagowda@kvafsu.edu.in

Introduction

Metabolic disorders in domestic animals refer to a group of conditions that affect the normal metabolic functions of animals. Metabolic disorders in crossbred dairy cows pose significant challenges to both farmers and veterinarians in India. These disorders have significant impacts on the health, productivity, and overall well-being of the animals. Metabolic disorders are relatively common in cattle, especially in high-producing dairy cows during the transition period around calving. The incidence rates can vary depending on various factors such as breed, management practices, and nutrition.

Nutritional Challenges and Dietary Practices in India

Availability and Quality of Feeds: In the Indian context, the availability and quality of feeds play a crucial role in the nutritional management of crossbred dairy cows. While India is an agrarian country with abundant feed resources, there are challenges in ensuring consistent and high-quality feed availability throughout the year. Farmers often rely on locally available feedstuffs such as crop residues, green fodder, and agro-industrial byproducts. However, these feeds may have variable nutrient composition and can be deficient in key nutrients like energy, protein, minerals, and vitamins. It is essential for veterinarians to educate farmers about the importance of feed quality and assist in identifying reliable feed sources.

Deficiencies and Imbalances in Nutrients: Many crossbred dairy cows in India suffer from nutritional deficiencies and imbalances, leading to metabolic disorders. Imbalanced diets with inadequate energy, protein, minerals, or vitamins can result in reduced milk production and increased susceptibility to metabolic disorders. Nutrient deficiencies are often prevalent in diets based on crop residues or low-quality forages. Veterinarians should emphasize the importance of formulating balanced rations that meet the specific nutrient requirements of crossbred dairy cows. Conducting regular feed analysis and providing appropriate supplementation can help address nutrient deficiencies.

Feed Management Practices: Feed management practices in India can vary significantly, and certain practices contribute to the occurrence of metabolic disorders. Irregular feeding patterns, abrupt feed changes, and inadequate access to fresh and clean water are common issues. Moreover, feeding high-concentrate diets without proper adaptation can increase the risk of ruminal acidosis and other metabolic disorders. Veterinarians should promote consistent feeding routines, gradual diet transitions, and the use of feed additives, such as buffers and yeast, to optimize rumen health and reduce metabolic risks.

Socio-economic Factors Affecting Nutrition: Socio-economic factors influence the nutritional management of crossbred dairy cows in India. Limited financial resources, inadequate knowledge about optimal nutrition, and traditional feeding practices can hinder the implementation of effective strategies. Veterinarians should work closely with farmers, providing practical solutions that consider the economic constraints. They can help farmers identify cost-effective feed alternatives, optimize resource utilization, and develop customized feeding programs that align with their specific circumstances.

General Recommended Interventions:

Proper nutrition plays a vital role in preventing and managing metabolic disorders in cattle. Key interventions include:

a. Balanced diet: Providing a well-balanced diet with appropriate energy, protein, mineral, and vitamin levels.
b. Transition management: Careful diet formulation during the transition period to meet the increasing energy demands while avoiding sudden dietary changes.
c. Dry cow management: Implementing effective dry cow nutrition programs to support the cow's health and prepare her for the upcoming lactation.
d. Monitoring body condition: Regular body condition scoring to ensure cows are neither too thin nor too fat, as both extremes can increase the risk of metabolic disorders.
e. Feed additives: The use of additives like yeast, probiotics, and buffers can help improve rumen health and reduce the risk of metabolic disturbances.

Nutritional Interventions:

In addition to balanced nutrition, there are several specific nutritional interventions that can be employed to prevent and manage metabolic disorders in cattle:

a) Energy management: Maintaining appropriate energy balance is crucial to prevent conditions like ketosis and fatty liver syndrome. Providing adequate energy in the diet, especially during the transition period, can help meet the increased energy demands of the cow. Managing body condition score and preventing excessive weight loss or gain. Properly formulating diets to meet energy demands during different production stages.

b) Fiber management: Ensuring an appropriate level of dietary fiber is important for rumen health and preventing ruminal acidosis. Including high-quality forage and avoiding sudden shifts to highly fermentable diets can help maintain a healthy rumen environment. Maintaining a balanced fiber-to-concentrate ratio in diets. Managing forage quality, processing, and particle size to optimize rumen function and prevent acidosis. Incorporating effective fiber sources, such as long-stem forages and high-fiber byproducts

c) Mineral supplementation: Providing adequate levels of minerals, such as calcium, magnesium, phosphorus, and potassium, is essential to prevent disorders like milk fever and hypomagnesemia. Balancing the mineral composition of the diet based on forage and water analysis can help prevent deficiencies or imbalances. Providing appropriate supplementation strategies for trace minerals, such as copper, zinc, and selenium.

d) Vitamin supplementation: Ensuring proper vitamin levels, particularly fat-soluble vitamins (A, D, E, and K), can support overall metabolic function and immune system health.

e) Water management: Access to clean, fresh water is critical for proper hydration and rumen function. Monitoring water quality and availability is important to prevent water-related metabolic disorders.

f) Protein and Amino Acid Management: Providing adequate protein and essential amino acids to support growth, lactation, and reproduction. Evaluating protein sources and optimizing rumen degradable and undegradable protein ratios. Implementing precision feeding techniques to enhance nitrogen utilization.

Preventive Strategies:

Prevention is always better than treatment when it comes to metabolic disorders in cattle. Implementing preventive measures can significantly reduce the incidence of these conditions. Some key prevention strategies include:

A. Proper prepartum management: Ensuring optimal nutrition, appropriate body condition, and minimizing stressors during the prepartum period.

B. Adequate transition period: Allowing cows a gradual transition from the dry period to the lactation phase, with careful attention to diet changes and monitoring for any signs of metabolic disorders. Implementing controlled transition diets during the pre- and postpartum periods. Minimizing negative energy balance and associated disorders like ketosis. Ensuring proper calcium and magnesium supplementation to prevent milk fever and hypomagnesemia.

C. Balanced ration: Formulating and providing a well-balanced ration that meets the specific nutrient requirements of the cows based on their production stage. Formulating Rations: Work closely with a nutritionist or utilize ration-balancing software to formulate diets that meet the specific requirements of different production stages and individual animals. Consider factors such as age, breed, physiological status, and environmental conditions when determining nutrient levels.

D. Feeding management: Implementing good feeding management practices, such as providing consistent access to fresh, clean water and avoiding abrupt changes in feed or feeding routines. Provide access to clean and fresh water at all times, as water intake is essential for optimal digestion and metabolic functions. Ensure proper feed storage and handling practices to prevent spoilage, contamination, and nutrient degradation. Implement a consistent feeding schedule and avoid sudden dietary changes that can disrupt rumen function and digestive health.

E. Silage and Forage Management: Employing proper ensiling techniques to prevent mold growth and mycotoxin contamination. Balancing nutrient composition and preserving forage quality during storage and feeding. Mitigating the risk of metabolic and respiratory disorders associated with poor-quality silage.

F. Regular monitoring: Regular herd health checks, body condition scoring, and metabolic profiling can help identify and address any emerging issues early on. Conduct routine analysis of feed ingredients and forage quality to ensure nutrient adequacy and consistency.

G. Herd Health Management: Managing the overall health of the herd is crucial in preventing and managing metabolic disorders. Some important aspects of herd health management include:

a. Vaccination and disease control: Implementing an effective vaccination program to protect against infectious diseases can help reduce stress and the risk of metabolic disturbances.

b. Parasite control: Maintaining a proper parasite control program, including deworming and pasture management, can improve overall health and nutrient utilization in cattle.

c. Hoof care: Regular hoof trimming and proper foot hygiene are important to prevent lameness, which can contribute to metabolic disorders.

d. Environmental management: Providing a clean and comfortable environment, with adequate ventilation and proper temperature control, can reduce stress and improve cow health.

e. Reproduction management: Ensuring proper reproductive management practices, including timely breeding, can help minimize metabolic challenges during the transition period.

f. Environmental Considerations: Optimize ventilation, temperature control, and air quality within housing facilities to minimize stress and respiratory challenges.

Manage grazing systems and pasture rotation to optimize nutrient intake, forage utilization, and overall animal health.

Address potential mycotoxin risks by implementing appropriate storage, handling, and testing procedures for grains and silage.

H. Record-keeping and Data Analysis: Maintaining accurate records and regularly analyzing herd data can provide valuable insights into the occurrence and management of metabolic disorders. Tracking individual cow performance, health events, feed intake, and production parameters can help identify trends, risk factors, and areas for improvement. This data-driven approach allows for targeted interventions and adjustments to nutrition and management practices.

I. Genetic Selection plays a role in the susceptibility of cattle to metabolic disorders. Some breeds and genetic lines may have a higher risk of certain metabolic disorders. Producers can work with breed associations and genetic consultants to select animals with improved genetics that are less prone to metabolic disorders. By considering genetic factors, producers can reduce the incidence of these conditions within their herds.

J. Regular Monitoring and Evaluation of the herd's health status are vital in managing metabolic disorders. This includes closely observing cow behavior and appetite, conducting routine physical examinations, and regularly assessing key parameters such as body condition score, milk production, and reproductive performance. By monitoring these indicators, any potential issues can be detected early, allowing for timely intervention and adjustments to management practices. Seek veterinary advice for periodic health assessments and consider diagnostic tests to identify potential deficiencies or imbalances.

Sample Ration Formulation:

To assist farmers in implementing the recommended nutritional interventions, a sample ration formulation is provided below. Please note that this is just an illustrative example, and it is essential to work with a nutritionist to develop rations specific to individual herd requirements and available feed resources.

Sample Ration for Lactating Dairy Cows with 16 % Crude Protein, 32 % Neutral Detergent Fiber (NDF) and 1.6 Mcal/kg Metabolizable Energy can be prepared as below -

Ingredients: Ration Formulation (percentage of dry matter):

1. Corn silage: 40%
2. Alfalfa hay: 20%
3. Soybean meal: 10%
4. High-moisture corn: 15%
5. Wheat bran: 5%
6. Minerals and vitamins: 0.5%
7. Fat supplement: 4%
8. Salt: 0.5%
9. Water: Ad libitum

KETOSIS

The primary cause of ketosis in dairy cattle is an imbalance between the energy intake and energy requirements of the cow, resulting in a negative energy balance. During early lactation, cows experience a surge in milk production, which increases their energy demand. If the cow cannot meet this demand through feed intake, it begins mobilizing body fat reserves to compensate. The excessive breakdown of fat results in the accumulation of ketone bodies, such as beta-hydroxybutyrate (BHB), acetoacetate, and acetone, in the bloodstream. Treatment options may include:

- Intravenous glucose administration: This helps provide a readily available energy source to overcome the negative energy balance.
- Oral propylene glycol: Propylene glycol is converted to glucose in the liver and can help increase blood glucose levels.
- Injectable glucocorticoids: In severe cases, glucocorticoids may be administered to stimulate glucose synthesis in the liver.
- Supportive therapy: Supportive care, including fluid therapy, vitamins, and minerals, may be necessary to address dehydration and maintain electrolyte balance.
- Management adjustments: Improvements in feeding management, including increasing energy-dense feeds, optimizing ration formulation, and enhancing feed palatability, may be recommended.

Specific Nutritional Strategies are -

1. Energy-dense diets: Formulate rations that meet the increasing energy demands of early lactation cows. Including energy-dense ingredients such as grains, oilseeds, and fats/oils can help meet the cow's energy requirements.
2. Rumen-protected choline: Supplementation of rumen-protected choline during the transition period has been shown to improve liver function and reduce the incidence of ketosis.
3. Bypass proteins: Including bypass proteins in the diet can enhance the efficiency of protein utilization and minimize the risk of excessive fat mobilization.
4. Fiber management: Ensure adequate fiber intake by offering high-quality forages and avoiding diets with excessively low levels of effective fiber. Sufficient fiber stimulates rumen function and helps maintain rumen health.

5. Feed palatability: Ensure that diets are palatable and appetizing to encourage cows to consume their full ration. Proper mixing, minimizing feed spoilage, and avoiding moldy or unpalatable feeds are important considerations.
6. Balanced nutrition: Provide a well-balanced diet, particularly during the transition period, to meet the increasing energy demands of early lactation cows.
7. Gradual dietary changes: Avoid sudden shifts in diet and gradually introduce new feeds to allow cows to adapt to dietary modifications.
8. Body condition management: Maintain appropriate body condition scores (BCS) throughout the lactation cycle, ensuring cows are not overconditioned at calving.
9. Adequate dry matter intake: Encourage optimal dry matter intake by offering high-quality forages, minimizing feed sorting, and optimizing feeding practices.
10. Stress reduction: Minimize stressors by providing a comfortable environment, proper ventilation, and reducing social disruptions during the transition period.

MILK FEVER

Milk fever, also known as hypocalcemia or parturient paresis, is a metabolic disorder that commonly affects dairy cows during the early stages of lactation. It occurs due to a sudden drop in blood calcium levels, which can lead to muscle weakness or paralysis. Milk fever is primarily caused by an imbalance between the calcium demands of the cow during early lactation and its ability to mobilize calcium from its body reserves or absorb calcium from its diet. High-producing dairy cows experience a sudden increase in calcium requirements at the onset of lactation, as they need to produce and secrete large amounts of milk. If the cow's dietary calcium intake is insufficient to meet these demands, it can lead to hypocalcemia. The treatment of milk fever involves raising the blood calcium levels in the affected cow. This is typically achieved through the administration of intravenous calcium solutions, such as calcium gluconate or calcium borogluconate. Veterinary assistance is required to administer these treatments effectively. In severe cases, additional supportive therapy, such as fluid therapy and anti-inflammatory drugs, may be necessary.

Specific Nutritional Strategies could be as below -

1. Dietary management: Balancing the prepartum diet to provide adequate, but not excessive, calcium and controlling the dietary cation-anion balance (DCAB) can help

prevent milk fever. A diet with an appropriate DCAB involves reducing potassium and sodium levels and increasing dietary calcium content.

2. Anionic salts supplementation: Feeding anionic salts to cows in the weeks leading up to calving can help acidify their blood, which aids in preventing milk fever.
3. Monitoring body condition: Maintaining optimal body condition scores throughout the dry period can reduce the risk of milk fever.

FATTY LIVER SYNDROME

Hepatic lipidosis, is a common metabolic disorder that affects dairy cattle, characterized by the abnormal accumulation of fat within the liver cells, leading to liver dysfunction. Typically occurs during the transition period in dairy cows, which is around 2 to 3 weeks before and after calving. During this period, cows experience a negative energy balance, where their energy intake is lower than their energy requirements. As a result, the body mobilizes stored fat to meet energy demands, leading to excessive fat accumulation in the liver. High-production, excessive body condition, sudden changes in diet, abrupt changes in diet, especially an increase in grain consumption and reduced dry matter intake disrupt the metabolic processes in the liver and promote fat accumulation.

Specific Nutritional Strategies are -

1. Nutritional support: Providing energy-dense diets and ensuring adequate dry matter intake are crucial for managing fatty liver syndrome. Intravenous glucose infusion or oral propylene glycol supplementation may be necessary to meet energy requirements.
2. Body condition scoring: Regular monitoring and maintenance of appropriate body condition scores during the dry period can help prevent excessive fat accumulation in the liver.
3. Balanced transition diets: Gradual diet transitions with a focus on maintaining energy balance are important. Diets should be formulated to meet the cow's nutritional requirements during the transition period.
4. Adequate dry matter intake: Ensuring sufficient dry matter intake is crucial to meet the energy needs of cows during the transition period.
5. Ruminal health: Promoting ruminal health through proper nutrition, such as providing adequate effective fiber and minimizing rumen acidosis, can help prevent fatty liver syndrome.

DISPLACED ABOMASUM

DA is a common condition in dairy cattle that occurs when the abomasum (the fourth compartment of the stomach) moves from its normal position to an abnormal location within the abdomen. It is most commonly seen in high-producing dairy cows during the early postpartum period. Primarily caused by the metabolic changes that occur during the transition period in dairy cows. These metabolic changes affect the motility of the gastrointestinal tract and can lead to the displacement of the abomasum. The exact cause of DA is multifactorial, with several risk factors such as increased dry matter intake during early lactation, reduced abomasal motility, hormonal imbalances, such as decreased insulin and increased growth hormone levels and poor rumen fill due to low-fiber diets or rumen acidosis and cow-level factors like breed, genetics, and body condition score. The primary treatment for displaced abomasum is surgical correction, which involves repositioning the abomasum to its normal location.

Specific preventive strategies are –

1. Providing a balanced transition cow diet to prevent metabolic disorders and promote rumen health. Maintaining a balanced diet with adequate fiber levels to promote rumen health and motility.
2. Transitioning cows to high-forage diets gradually to stimulate rumen function and avoid acidosis.
3. Ensuring a sufficient supply of physically effective fiber to stimulate rumination and maintain rumen pH.
4. Providing optimal energy and protein levels to meet the cow's requirements during the transition period.
5. Maintaining a consistent and gradual increase in dry matter intake after calving.
6. Avoiding sudden dietary changes and excessive amounts of fermentable carbohydrates.
7. Ensuring proper body condition score before calving.

RUMEN ACIDOSIS

It is a metabolic disorder that affects dairy cattle, specifically their rumen, which is the largest compartment of their stomach. It occurs when the pH of the rumen becomes too low, leading to an imbalance in the microbial population and disruption of normal digestive processes. The primary cause of rumen acidosis is an imbalance in the rumen's microbial population due to the consumption of excessive amounts of highly fermentable carbohydrates. This typically happens when cows are fed a high-concentrate diet, which includes ingredients like grains, starches, and easily fermentable sugars. The rapid fermentation of these carbohydrates produces large amounts of volatile fatty acids (VFAs), particularly lactic acid. The accumulation of VFAs, especially lactic acid, lowers the rumen pH, leading to acidosis. The treatment of rumen acidosis involves several approaches, including removing the source of fermentable carbohydrates, correcting rumen pH and supportive care.

Specific Nutritional Strategies are -

1. Gradual diet transitions: Avoid sudden changes in the cow's diet and provide a transition period when introducing new feed ingredients or changing the ration.
2. Balanced ration: Formulate a balanced diet that meets the cow's nutritional requirements while considering the rumen's fermentation capacity. Include an appropriate proportion of fiber to promote rumen health. Feed management: Ensure consistent feed delivery and avoid overfeeding of grains or concentrates. Monitor feed refusals regularly to assess the adequacy of the diet.
3. Adequate fiber content: Include adequate levels of physically effective fiber (e.g., forages, high-quality roughage) in the diet to stimulate rumination and maintain a stable rumen pH.
4. Slowly fermentable carbohydrates: Replace some rapidly fermentable carbohydrates with slower-release energy sources like fibrous feeds or fats.
5. Buffering agents: Add buffering agents, such as sodium bicarbonate, to the diet to help stabilize rumen pH and prevent acidosis.

LOW MILK FAT SYNDROME

Also known as milk fat depression, is a condition observed in dairy cattle where there is a significant decrease in the fat content of their milk. It is a complex condition influenced by various factors, including nutrition, rumen metabolism, genetics, and management practices. The primary cause is an alteration in rumen fermentation patterns, specifically a decrease in the production of volatile fatty acids (VFAs), such as acetate, and an increase in the production of propionate. This shift in rumen fermentation leads to reduced milk fat synthesis in the mammary gland. The specific etiological factors contributing to low milk fat syndrome includes 1. High levels of unsaturated fatty acids (UFA) in the diet, 2. Low effective fiber content in the diet, 3. Changes in rumen microbial populations 4. Genetic factors: Some individual cows may be genetically predisposed to low milk fat synthesis due to variations in genes involved in fatty acid synthesis and metabolism.

Specific preventive strategies are –

1. Dietary modifications: Adjusting the diet to restore rumen fermentation balance and optimize milk fat synthesis. This typically involves increasing the dietary levels of physically effective fiber, reducing the proportion of non-fiber carbohydrates, and ensuring a balanced fatty acid profile by incorporating appropriate sources and levels of fat, including rumen-protected fats when needed. Ensuring a sufficient supply of high-quality forages to maintain rumen health and function.
2. Supplementation: Providing specific feed additives, such as rumen-protected fats, can help overcome the negative effects of excessive unsaturated fatty acids and stimulate milk fat synthesis.
3. Management changes: Implementing appropriate feeding management practices, including feed formulation, ration balancing, and feeding frequency, can play a crucial role in managing low milk fat syndrome.
4. Genetic selection: Breeding programs can focus on selecting animals with desirable milk fat composition and metabolism, which can help reduce the prevalence of low milk fat syndrome in the herd.

LOW SNF (SOLIDS-NOT-FAT)

Low SNF condition in dairy cattle refers to a decrease in the concentration of solids, excluding fat, in their milk. This condition can negatively impact milk production, overall health, and reproductive performance in dairy cows. The major causes for the condition includes 1. Nutritional Deficiencies: Inadequate dietary intake of essential nutrients like carbohydrates, proteins, minerals, and vitamins can lead to low SNF in cattle, 2. Imbalanced Rations: Diets that have imbalanced ratios of energy and protein, or deficiencies in specific amino acids, can contribute to low SNF, 3. Poor Forage Quality: Low-quality forages lacking in nutrients can negatively impact the SNF content of milk, 4. Water Quality: Contaminated or poor-quality water can affect the cow's overall health and milk composition, including SNF, 5. Heat Stress:

High ambient temperatures and humidity levels can reduce feed intake and lead to low SNF and 6. Disease or Metabolic Disorders: Certain diseases and metabolic disorders, such as mastitis, ketosis, or acidosis, can disrupt normal milk synthesis and composition.

Specific Nutritional Strategies are -

1. Nutritional Management: Adjust the cow's diet to meet her energy, protein, mineral, and vitamin requirements. Provide good-quality forages with optimal nutrient content.Work with a nutritionist to formulate a balanced ration and ensure optimal intake.
2. Address Underlying Health Issues: Treat any concurrent diseases or metabolic disorders to restore normal milk composition.
3. Improve Water Quality: Provide clean, fresh water to the cows and ensure its quality is suitable for consumption.
4. Environmental Management: Implement strategies to mitigate heat stress, such as providing shade, proper ventilation, and cooling systems.
5. Regular Health Monitoring: Conduct regular veterinary check-ups to identify and treat any health issues promptly.
6. Proper Milking Procedures: Maintain strict hygiene during milking to prevent udder infections like mastitis, which can impact milk quality.

Apart from the previously mentioned metabolic disorders, there are a few others worth noting:

a. **Lactic acidosis**: A condition caused by an overgrowth of acid-producing bacteria in the rumen due to excessive intake of readily fermentable carbohydrates. Prevention involves proper diet formulation and avoiding sudden dietary changes.
b. **Hypomagnesemia** (Grass tetany): A deficiency of magnesium often associated with grazing on lush, rapidly growing pasture. Prevention involves providing magnesium supplementation and ensuring a balanced diet.
c. **Polioencephalomalacia** (PEM): A neurological disorder resulting from thiamine (vitamin B1) deficiency. Prevention includes proper nutrition, especially thiamine supplementation in high-concentrate diets.

Economic Considerations:

Metabolic disorders in cattle can have significant economic implications for producers. Apart from the direct costs associated with veterinary treatments and medications, there are indirect costs such as reduced milk production, decreased fertility, increased culling rates, and decreased overall herd profitability. Therefore, implementing effective preventive measures and management strategies to minimize the occurrence of metabolic disorders can have a positive impact on the financial viability of the operation. Conduct a thorough cost-benefit analysis to evaluate the economic feasibility of implementing comprehensive nutritional management strategies. Consider factors such as feed costs, labor requirements, potential reductions in veterinary expenses, and improvements in production efficiency and performance.

In conclusion, effectively managing metabolic disorders in cattle requires a holistic approach that encompasses preventive measures, proper nutrition, regular monitoring, collaboration with experts, and continuous education.

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Chapter 5
ADVANCES IN FEEDING MANAGEMENT OF TRANSITION PERIOD

Dr Kamdev Sethy
Assistant Professor
Department of Animal Nutrition
College of Veterinary Science and Animal Husbandry, OUAT, Bhubaneswar
Email: babuiviri@gmail.com

Introduction

Dairy farming is a business that people engage in for financial gain. Unfortunately, the quest for optimal economic efficiency frequently places the dairy cow in a state of compromised welfare or poor health. In both intensive and extensive dairy production systems internationally and nationally, the goals of economic efficiency and optimal dairy cow health are often in conflict. The relatively recent developments in animal breeding have produced dairy cows with enormous losses of body nutrients to support milk production. Production diseases of the dairy cow are associated with a level of production inconsistent with nutrient intake, provision of an unsuitable diet, an inappropriate breeding policy or an unsuitable environment. Production diseases are important for dairy cows as they constitute a major proportion of the common health problems encountered on dairy farms and because they predispose cows to infectious diseases, infertility, production losses and lameness. They compromise the health and welfare of dairy cows and ultimately reduce the farmer profitability (Mulligan and Doherty, 2008).

The transition period for dairy cows generally extends from 3 weeks prior to parturition through 3 weeks after parturition (Smith and Risco, 2005). During this period dairy cattle are at a high risk for most of the metabolic diseases which is characterized by marked changes in their endocrine status that are much more dramatic than at any other time in the lactation–gestation cycle and a reduction in feed intake when nutrient demand for the developing conceptus and the impending lactogenesis are increasing (Grummer, 1999). Transition period is especially critical for health and subsequent performance of dairy cows. Dairy cattle are more susceptible to a variety of metabolic and infectious diseases during the transition period compared with peak lactation (Sharma *et al*., 2011). Physiological changes during transition period associated with rapid differentiation of secretory parenchyma, intense mammary gland growth and the onset of copious milk synthesis and secretion are accompanied by a high-energy demand and an increased oxygen requirement. This increased oxygen demand augments the production of oxygen-derived reactants, collectively termed reactive oxygen species (ROS). Excessive production of free radicals and concomitant damage at cellular and tissue levels are controlled by cellular antioxidant defence systems. When ROS are produced faster than they can be safely neutralized by antioxidant mechanisms, oxidative stress results There are growing evidences that oxidative stress is a threat to transition period and an increase in its level may lead to delivery/calving-related complications in both man and animals (Dimri *et al*., 2010). Health problems during the transition period can easily erase the entire profit potential for an individual cow in that lactation, through increased costs for veterinary treatment and lost production potential (Arshad *et al.,* 2020). Nutrition not only has a direct effect on reproductive performance, but can influence reproductive potential through its mediation of periparturient disease prevalence. Management practices focused to ensure good health or prevent serious postpartum disease conditions are also important in managing reproductive performance. Reproductive performance of dairy cattle needs to be approached on a herd basis.

Physiological and metabolic changes during the transition period

Dry matter intake

Dry matter intake starts to decrease a few weeks before parturition with the lowest level occurring at calving (Kvidera *et al.,* 2017). Average values for the prefresh transition period have been reported to range between 1.7 and 2.0% of body weight (BW) (Hayirli *et al*., 2002) However this is not a constant value and it can be influenced by the ration that is fed (concentration of nutrients), the stage of the transition period, body condition score (BCS) and parity. Dry matter intake decreases about 32% during the final three weeks of gestation, and 89% of that decline occurs at five to seven days before calving (Hayirli *et al*., 2002). As a percentage of body weight, heifers consume less feed than cows at 21 days before calving.

Endocrine and metabolic changes

Alterations in neuroendocrine function in response to a stressor affect nearly all functions of animal production, including metabolism, reproduction, lactation, immune competence, and behavior. These alterations include not only the classic neuroendocrine response to stress, but also may include changes in the pituitary secretion of prolactin, growth hormone, thyroid-stimulating hormone, and the gonadotropins (Hernandez-Castellano *et al*., 2017). Endocrine and metabolic changes in transition dairy cows are affected by prepartum infusions of a serotonin precursor. Serotonin (5-HT) has been shown to be involved in calcium homeostasis, modulating calcium concentration in blood. In addition, 5-HT participates in a variety of metabolic pathways, mainly through the modulation of glucose and lipid metabolism. The prepartum administration of 5-hydroxy-l-tryptophan (5-HTP), a 5-HT precursor, would affect endocrine systems related to calcium homeostasis, and interact with other endocrine and metabolic pathways during the transition period.

Glucose and Lipid Metabolism

Glucose and amino acids are the major fuel supply of the developing foetus in ruminants. Glucose and amino acids are also needed by the mammary gland for lactose and milk protein synthesis, respectively. Ruminants are not entirely dependent on dietary glucose; as a result they are in a constant stage of gluconeogenesis (Kvidera *et al.,* 2017). The major gluconeogenic precursor in ruminants is propionic acid produced in the rumen. Its contribution to gluconeogenesis has been estimated to be 32 to 73% (Sumner *et al.,* 2007). Liver uptake of propionate by portal circulation is almost 100% (Bines and Morant, 1983) ; however the capacity of the liver to convert propionate to glucose seems to be responsive to the amount of propionate supplied and the physiological stage of the animal. Hepatic propionate metabolism is modulated during the transition period. As an example, hepatic blood flow in cows increases 84% from 11 d prepartum to 11 d postpartum (Reynolds *et al*., 2003). In addition, propionate conversion to glucose by the liver is 19 and 29% greater at day 1 and 21 postpartum, respectively, than at day 21 prepartum (Overton *et al*., 1998).

Periparturient disease and reproduction

Veterinarians recognize the critical nature of the transition period as it relates to periparturient disease. Periparturient diseases are the scourge of the dairy industry. Total financial losses associated with periparturient diseases result from lost and discarded milk, veterinary fees, increased labor, pharmaceuticals and premature culling. Reproductive performance is also adversely affected by periparturient disease. Conception rate (CR) for cows that have experienced at least one periparturient disease incident is 35% lower as compared to cows with a disease-free calving (Reynolds *et al*., 2003).

Milk Fever, Parturient Paresis, Hypocalcaemia

Milk fever is a non-febrile metabolic disease affecting milking cows in which acute calcium deficiency causes progressive neuromuscular dysfunction with flaccid paralysis, circulatory collapse, and depression of consciousness (Santos *et al.,* 2019).

Ketosis and Fatty Liver

Ketosis is defined as a metabolic disease characterized by high levels of ketone bodies affecting cattle, sheep and goats. Ketosis affects dairy cows in the period from parturition to 6 weeks postpartum (DeGaris *et al.,* 2010). There are two types of ketosis, primary and secondary. Cattle with primary clinical ketosis have a decreased appetite and elevated serum, milk, urine or breathe ketones in the absence of another concurrent disease (DeGaris *et al.,* 2010)

Retained Foetal Membranes - Metritis Complex

Retained Foetal Membranes is defined as the lack of detachment of foetal membranes from the maternal caruncles within the first 12 to 24 hours after calving (Lean *et al.,* 2019). Hypocalcaemia results in reduced neutrophil function and increases risk of retained foetal membranes. Retained foetal membranes have been the major factor that predisposes cattle to metritis.

Abomasal Disorders

Displacements, dilatations, and volvulus of the abomasum are the most commonly encountered disorders of the gastrointestinal tract in modern dairy operations (Trent, 1990)[18]. Displacement can be on the left side (LDA) or the right side (RDA). Omental attachments of the abomasum prevent true torsion around the long axis of the abomasum, with rotation occurring around an axis through the supporting lesser omentum. Therefore, a more accurate term for the syndrome is "abomasal volvulus", rather than torsion. Any right-sided displacement that requires further manipulation to free the pylorus and duodenum may be considered for practical purposes to be a volvulus (Trent, 1990).

Feeding management of transition cow

Feeding a cow during the transition period is a challenge due to the nutritional and physiological changes that occur during this period (Grummer, 1999) . To increase the potential for successful reproduction and prevent periparturient diseases, following are the critical control points during transition period that need to be addressed:

1. Maximizing dry matter intake

Cows that experienced periparturient disease have shown that there was a greater decline in dry matter intake. Restricting DMI in the dry period allows cows to increase DMI immediately postpartum, resulting in higher energy balances, and decreased body fat mobilization, evident by lower NEFA (non-esterified fatty acid) and BHBA (beta hydroxyl butyrate) concentrations (Dann *et al*., 2005).

2. Maintaining lactation ration

Feeding higher-fibre concentrates which enable higher intakes, reduce milk yield compared to higher starch rations. A practical approach for maintaining energy intake in late gestation is to provide limited amounts of lactation ration to 'close-up' cows, and remove straw from their ration. The higher energy concentration of the lactation ration compensates for any reduction in intake, adaptation of the rumen is allowed, and fill of indigestible fibre is reduced, enabling more rapid rumen turnover and greater intake after calving.

3. Stimulating rumen papillae development

Rumen papillae helps to maintain acid-base balance in the rumen by absorbing volatile fatty acids and especially lactate, generated by microbial fermentation. Growth of these papillae is influenced by the presence of fermentation products, primarily propionate and butyrate and not acetate. Higher fibre diets predominately produce acetate during fermentation, which results in a reduction in papillae length. Adding fermentable non-structural carbohydrates to the late gestation diet can have positive effects by initiating rumen papillae growth and allowing rumen organisms to adapt to the starch substrate. Adapted rumen papillae to grain diet during a prepartum helps to facilitate the transition to a high grain diet during post lactation stage. This would potentially allow the cow to increase DMI more rapidly postpartum and minimize the disease problems associated with ruminal acidosis and displaced abomasum (Andersen *et al*., 1999).

4. Maintaining calcium homeostasis

The onset of lactation causes a severe and rapid drain on blood calcium required to produce milk. If this blood calcium is not replaced as rapidly as it is reduced via bone calcium release (resorption) or intestinal absorption of calcium, cows will become hypocalcaemia with some developing clinical milk fever (Santos *et al.,* 2019). Reducing DCAD (dietary cation-anion difference) to negative values has been shown by many authors to prevent this rapid decline in blood calcium at calving. DCAD should be less than zero postpartum (-10 to -15 meq/100 g dry matter if forages are variable in potassium levels).

5. Minimizing negative energy and protein balance

Excessive energy intake leads to 'fat cow syndrome'. Feeding gluconeogenic precursors such as propylene glycol has also shown positive effects on energy status of the late pregnant cow. Prepartum protein depletion adversely affects periparturient metabolic status, resulting in a greater incidence of ketosis and fat cow syndrome. Energy balance of a transition cow is determined by subtracting energy requirements for maintenance and gestation from energy intake. During the transition period, feed intake is decreasing at a time when energy requirements are increasing due to growth of the conceptus. Consequently, to maintain the energy balance the energy density of the diet should increase. Feeding higher protein during the transition period reduced feed intake or milk yield postpartum (Rodney *et al.,* 2015)

6. Minimizing immune dysfunction

The immune system of the cow has been shown to decline in response to the transition period, possibly as a result of increased cortisol secretion associated with stress of late gestation and calving. Neutrophils are a type of white blood cell involved in the first line of defence against infection (Nelson *et al.,* 2016). It has been reported that the function of neutrophils is impaired in transition dairy cows leading to a state of immunosuppression. Elevated blood NEFA concentrations before calving have been linked with uterine disorders and impaired neutrophil function (Doepel *et al.,* 2002). Therefore, the metabolic demands of lactation can affect the cow's ability to recover from immunosuppression (Kehrli *et al*., 2006). Micro minerals and vitamins supplementation recover from immune function problem.

Conclusion

Transition period is the most important period during which considerable metabolic adjustment occurs in dairy animals. Sub-optimal nutrition during this time period may impart nutritional stress on the cows leads to many periparturient disorders. Attention must be given to formulating appropriate diets for cows during this period.

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Chapter 6
CURRENT STATUS, CHALLENGES AND THE WAY FORWARD FOR SHEEP AND GOAT PRODUCTION

Dr. Jaishankar, N
MVSc, PhD, IDAF (The Netherlands)
Associate Professor and Head, Department of Animal Nutrition
Veterinary College, Hassan, KVAFSU, Bidar
Email: drjaishankarn@gmail.com

INTRODUCTION

Small ruminants are typically raised by landless or resource-poor farmers in rain-fed locations, where their average agricultural holdings are either very small (marginal and small farmers) or insufficient to devote to crop cultivation. More than 60% of those employed in agriculture are either marginal or small farmers, with average land holding sizes of 1.32 hectares (2000–01), 0.68 ha in 2020, and predicted to be low 0.32 ha in 2030 (ICAR Vision, 2030). The size of land holdings is shrinking daily as a result of the rising population, and urbanization thus, an increasing number of farmers are losing their farms or being landless. The socio-economic development of our nation is significantly influenced by farming. Most of the agricultural workforce about 80% of work in the livestock-rearing industry and live in poverty. Sheep and Goat rearing would potentially be a source of income for them.

The livestock sector contributes 6.2% GDP and 30.9% of total agriculture GDP in 2022 (RBI 2022). Total Sheep population in India is 74.26 millionin 2019 increase by 14.13% over previous census, Telangana ranks first and had 19.1 million followed by Andra Pradesh 17.6 million, Karnataka has 11.1 million sheep. In Karnataka, the well-known sheep breeds are Bandur/Mandya, Hassan, Deccani, Bellary, Kenguri, Tumkur and non-descript local sheep which are prevalent in specific parts of the state. The Goat population in the country in 2019 is 148.89 million showing an increase of 10.14% over the previous census. About 27.8% of the total livestock is contributed by goats, Rajasthan ranks first position (20.84 million) followed by West Bengal 16.28 million and Uttar Pradesh 14.48 million (Karnataka ranks 10th position 6.17 million) as per, Livestock Census, (2019).

The Per capita mutton and chevon availability in Karnataka state is 1.23 kg/year, equivalent to 3.4 g/day (India meat comsuption 4kg vs world average 43kg), Sheep and goat production are emerging as the potential meat producers in the future, it is a significant source of gainful employment and supportive of rural livelihood and entrepreneurship, Sheep have the potential to produce 1.5 lamb per breedable ewe whereas those breeds with booroola gene (FecB) can produce 3 lambs/breedable ewe per year, Most meat goat breeds produce twins and triplets and hence can produce 3 to 4.5 kids per breedable ewe per year.

SWOT analysis of Sheep and Goat Farming Sector in India

STRENGTHS

India is the having second highest Sheep & Goat population after China. These small ruminants have ability to adapt to the harshest situations; hence can be reared at various geographical areas. Capability to survive and produce on coarse and poor quality feed and fodder resources, therefore low investment to initiate the activity. Indigenous breeds has good potential and resistant for most of the diseases. There is availability of veterinary facility at village level for livestock farmers. Large amount of Indigenous Technology Knowledge (ITK) available with the livestock keepers for management of small ruminant, Demand for wool and meat at local markets market and emergency source of income for livestock farmers.

WEAKNESSES

Lack of marketing infrastructure facilities for Value addition such as meat processing, warehousing, Cold storage, refrigerated vehicles. Unorganized structure of sector, Absence of Public Private Partnership, Lack of demand driven interventions, Low income / productivity / production efficiency, Lack of manpower in the traditional system, absence of sufficient System of financial support, Low productivity of some breeds, absence of a fixed monthly salary, lack of good management practices during disease condition and Poor technical training of sheep growers/farmers.

OPPORTUNITIES

Low production costs for rearing small ruminants when compared to other breeds and animal species, The rising demand for meat and wool, Integrated Systems Farming/ Mixed Species Farming is beneficial with higher profits, Untapped potential for the export & value added products, Modern production technologies, particularly to rural women and youth, Sheep and goat can be used as a tool to alleviate poverty while also ensuring food security, processing to add value to sheep and goat product, Gainful employment, Self empowerment and entrepreneurship development and scope for marketing of meat and wool could be organized.

THREATS

Extreme climatic conditions and natural calamities, Invasion of diseases, Depletion of natural resources continued decreasing land under fodder production and pasture, increased human population pressure, grazing areas are of difficult access to the shepherd, social discrimination of the shepherd.

Types of Challenges

The future well being of the Indian sheep industry depends on the potential for profitability, which is affected by various challenges.

Technical Challenges

Unavailability of high Genetic Potential breeds of Sheep, Absence of high productive exotic breed for Crossbreeding, Lack of Scientific feeding practices, Disease management health challenges like PPR,CCPP etc., High lamb mortality, Proper animal health services and availability of drugs

Commercial Challenges

Marketing facilities, Unorganized nature of the sector, Endemic disease problems, and trans-boundary disease risks, Feed resources (Grassland based ruminant systems are largely dependent on pasture grazing) and Feed supply chains (compound feed mixing and milling) and Institutional support for entrepreneurship.

Other Challenges

Competition for resources, Climate change, Socio-cultural modifiers, Ethical concerns as a driver of change and Wildcard drivers of change.

Systems of rearing

Tethering system: 1-2 sheep or goat reared by farmers, (Grazing or Browsing with limited area). Animal is tied to the rope of 3-5meters length, which permit sheep and goat to consume roughage in limited area, repeatedly the location will be changed to get sufficient feed resources to meet the requirements.

Extensive system: In this system, availability of energy & protein for more than half of the year is less than the requirements. This system leads to low productivity as most of the energy is diverted for physical exercise. Sheep weigh only 15-16 kg at 9-12 months of age, the average daily gain would be less than 50g, sheep reared in this system shown Lower dressing percentage (35-40%) and narrow bone:meat ratio (1:4). There production is also affected with high mortality in lambs and kids. Goats are browser and have selective feeding pattern preferred to rear in this system.

Semi-Intensive system: It is a combination of free range grazing and stall-feeding, Poor nutritive value of native pastures and crop residues makes it necessary to improve the nutrient intake for better animal performance, Free grazing for 4-6 h/d & supplementation with roughage and 2.0 % of body weight with concentrates, Supplementation with concentrates has been shown to increase dressing percentage, lambing and kidding percentage, increased birth weight of lambs and kids and reduced mortality, and increased wool yield. In addition to grazing, pregnant ewes & lactating ewes were supplemented with 300g/d concentrate feed mixture (12 % DCP & 65 % TDN). Both sheep and goat can be reared in this system.

Intensive system: The intensive system of sheep includes complete stall feeding on cultivated fresh or conserved fodders, crop residues and concentrates. This system requires high labour and capital investment, judicious use of available feed and fodder resources, crop residues, agro-industrial byproduct is possible. Energy wasted for grazing can be conserved for growth and production, complete diets containing tree leaves/crop residues/legume hays or grass hay and concentrates in the ratio of 50:50. Least cost feed formulations: Leguminous fodders, tree and shrub leaves, cheaper energy supplements (jowar, bajra, etc) and protein supplements (mustard cake, guar meal, and sunflower cake). Sheep preferred to rear in this system at urban and semi-urban areas.

General Nutrition of Sheep and Goat

Feed accounts more than 60% in the total cost of sheep or goat rearing

DMI: The Dry matter intake is 2.5-3% DM of their live weight, 4-5% during growth stage

Water: Normally a sheep will drink water approx. 2-3 lit./kg dry feed consumed which will be doubled in lactation and heat stress condition

Protein: Methionine first limiting amino acid, N:S ratio should be 10:1 when NPN sources supplementation, molasses contain sulphur, hence no need to provide additional sulphur while blending molasses with NPN source for urea ammoniation or enrichment of dry fodder. DCP requirement for maintenance is $1/10^{th}$ of TDN or 1gm for every 1kg body weight whereas, DCP requirement increases by 50% during pregnancy and 100% during growth and lactation.

Energy: Non-pregnant, non-lactating ewe requires 10gm TDN per kg live weight for maintenance and wool production, the energy requirement will be 50% more at last 6wks of pregnancy and 100% more at first 10wks of lactation.

Minerals and Vitamins: 15 minerals essential out of which 7 are major mineral i.e. Na, Cl, Ca, P, Mg, K & S, NaCl added @ 0.5% in complete diet and 1% in conc. Good roughage satisfy all the vitamin needs as B Vitamins synthesized by rumen microbes and pasture generally contain Vitamin A and Vitamin E.

Strategies to increase sheep and goat production

Improved breeding and genetics for selection of the best among the locals as against going for crossbreeding, as the local breeds are well adopted to the environment and has resistant for most of the diseases. There is a need for conservation and efficient utilization of feed resources, in our country the most of the livestock reared on crop residues and even today we observe the crop residues burnt on fields because of poor palatability and lack of labours for procurement. Need to educate various technologies for efficient use crop residue for example: urea ammoniation of dry fodder, total mixed ration are the best option for utilization of poor quality crop residues as livestock feed. Large breed versus small breeds as large breeds mature slowly when compared to small breeds and the male: female ratio, ram to ewe ratio should not more than 1: 40 for reproduction. the animals should attain BCS of 2.75 to 3 in breeding ewes followed by induction of breeding ram into the flock is preferred way of inducing estrus synchronization.

Feeding and management of pregnant ewes

Gestation period in sheep and goat is 143-151 days, in the last two months of pregnancy, ewes should get adequate nutrition. But excessive energy intake results in fattening, the body condition score should be monitored regularly and feeding is adjusted as per BCS. Low energy intake results in low birth weight, weak lambs and reduced viability of lambs, need to provide 150-250g concentrate in semi-intensive system, add vitamin premix @25g/100kg of feed in intensive system, attaining a BCS of 3.5 to 3.75 is necessary to get healthy lambs and good colostrum yield following lambing. This would prevent lamb mortality, Make sure to feed colostrum as soon after lambing as possible. At lambing, Put ewes about to lamb in clean quarters, Feed dry fodder (hay) and avoid concentrates, Make sure to feed lambs with colostrum as soon after birth as possible, ewes well fed during late pregnancy would yield higher colostrum and quick let down of colostrums to nourish young ones. The peak milk yield in Mandya breed of sheep is observed in 2nd week after lambing hence, ensure the quantity of milk consumed by lambs for their health and growth performance as there linear increase in the lamb body weight gain against milk consumption. It is reported that negative energy balance is observed in lactating ewes in first month after lambing, therefore additional supplementation of balanced ration could minimize the adverse effects of negative energy balance in preventing the incidence of metabolic diseases like pregnancy toxaemia. Loss of body weight during lactation delays onset of post partum estrus, thereby increase interlambing interval. To prevent mineral deficiencies the mineralized salt lick blocks should be hanged near to animals, which also increase dry matter intake.

Lamb rearing and early weaning

Distinct advantage of early weaning is the reduction in inter-lambing interval, as the inter-lambing interval is reduced the number of births in a year can be increased and accelerated lambing is achievable through good management and feeding practices. The development of lambs in the first 4 months is faster than the kids. Most critical period is first 48 hours after lambing, if a lamb is unable to nurse within half an hour after birth, it should be assisted to suckle to get the advantage of colostrums (passive immunity). Lambs should be allowed to suckle thrice a day upto one month and there after twice a day. Through artificial feeding with milk replacers or with cow milk or goat milk, lambs can be weaned from day 2, but this is expensive. If cow or goat milk is to be used as milk substitute for lambs, blend with coconut oil to increase fat content of milk. Introduce solid feed from 7th day to train lambs to eat solid feed (creep feed should contain 18-20% CP and >70% TDN upto 12 wks) and from 15th day gradually start good quality hay (Coarse ground), lambs start eating significant amount of solid feed by about 6 weeks, When solid feed intake is about 0.75% of the body weight, lambs can be weaned, i.e., by about 6 weeks. Feeding grains or creep feed in mash form is advantageous for better rumen development.

Feeding of weaned/ grower lambs

While milk feeding, lambs can put on 100 to 120 g weight gain in small breeds and perhaps 200 to 250 g in large breed, but it depends on the quantity and quality of milk produced by the ewes, The ratio of milk intake to gain varies from 4:1 to 8:1 depending on total solid and fat content in milk. Milk composition is influenced by the quantity and quality of feed and fodder fed to ewes. The potential starter feeds for pre-ruminants are dried leguminous tree leaves or hay, germinated horse gram and low fibre containing feeds. Lambs have preference for leguminous hay than green fodder especially lucerne hay.

Extensive system doesn't fulfill the requirement of grower lambs, need to supply additional nutrients through concentrate feed mixture, the concentrate mixture should contain 13% CP and 70% TDN. Fattening is an additional cost in raising sheep and goats, as fattened animals are preferred in some countries but not very much in India, in places where meat is used for curry preparation, a little fat is preferred but not too much, therefore feeding management must be tailored to avoid too much of fat accumulation. To prevent mineral deficiencies in lambs and kids, mineralized salt licks should be accessible which also increase dry matter intake.

The following are some of the examples of feeding lambs during various situation based on availability of feed resources:

I. Feeding with Maize green fodder, Hedge Lucerne and concentrate feed mixture (CFM) to meet 100g gain per day as per nutritional requirement specified by ICAR 2013. In general the concentrate feed mixture with levels of 30:40:30 (Cereals:Oil cakes: Brans) + 2kg MM+1kg salt.

Body weight of lamb (kgs)	Maize green fodder (kg)	Hedge Lucerne (kg)	CFM (g)
10	0.75	0.75	175
15	1.0	1.0	200
20	1.5	1.0	200
25	1.5	1.0	300

Cereal fodder with leguminous fodder supplementation minimize the requirements of concentrate feed, hence the production cost can be minimized. It is recommended to feed leguminous fodder for growth and production of sheep and goat.

II. Feeding with Maize fodder silage and Concentrate feed mixture

Body weight (kgs)	Maize fodder silage (Kg)	CFM (g)
10	1.0	250
15	1.0	300
20	1.5	300
25	1.5	350

III. Feeding with Sorghum stovers/Ragi straw and Concentrate feed mixture

Body weight (kgs)	Sorghum stovers/ Ragi straw (g)	CFM (g)
10	200	300
15	250	375
20	300	450
25	400	450

IV. Feeding with Urea enriched dry fodder and Concentrate feed mixture

Body weight (kgs)	Urea enriched dry fodder (Kg)	CFM (g)
10	0.35	200
15	0.4	250
20	0.5	300
25	0.5	400

Animals need to be adopted for feeding of urea enriched dry fodder; care should be taken not to feed urea enriched dry fodder or other urea blended products for the lambs or kids less than three months old.

V. Feeding with Tree fodder, Sorghum stovers/Ragi straw and Concentrate feed mixture

Body weight (kgs)	Tree fodder (Sesbania/ Moringa) (kg)	Sorghum stovers/ Ragi straw (g)	CFM (g)
10	1.0	100	150
15	1.0	100	200
20	1.0	200	250
25	1.0	200	350

Feeding tree fodders are advantageous, as the tannin content of tree fodder improve protein digestibility.

Feeding of Lactating/suckling ewes

Only a little grain mixture should be given for first 2-3 days along with good quality fodder, so that the rumen microbes adopt for utilization of concentrate feed mixture, after 10 days upto weaning 250 g of concentrate mixture may be supplemented with good quality leguminous hay. A minimum of 3% fat in sheep ration is essential; common salt is added at the rate of 0.5% in complete diet or 1% of concentrate mixture. Supplemental feeding of concentrate mixture should gradually diminished at 8-10 weeks and can be stopped after 12-13 weeks of lambing i.e. at weaning, There after the ewes are maintained on grazing alone.

Feeding of Breeding Ewes (Flushing)

Flushing: Nutritional care of breeding ewes 3-4 weeks before mating by providing additional concentrate mixture. The effect of flushing is more evident in ewes that were underfed. Most of sheeps are bred 2-3 weeks after the onset of rains as grazing conditions are improved by this time. To obtain increased lambing rate, breeding ewes should be given 250 g concentrate mixture or 500 g hay/head/day 3-4 weeks before breeding.

Feeding of Ram/Buck

The dry matter intake in Ram/Buck is 3-3.5% of body weight, with available good quality pasture, allow Ram/Buck to browse/graze 6-8 hr per day, which will meet its nutritional requirements, with poor quality pasture provide concentrates mixture of 250 g/day. Under intensive system, separate feeding done with supplementation of roughage with 500g of concentrate feed mixture.

High Forage Production system

In our feeding system energy and protein, especially the rumen degraded proteins are the major constraints, but the technical people seem to be worried more on bypass protein, instead the rumen has to be fed well to feed the rumen microbes that provide protein and energy to the animal. High protein forages are the sustainable rumen degraded protein sources, hence, promote high protein forages cultivation, mix high protein forage with grasses and feed, the best preferred forage with grasses for small ruminants are any thin stemmed grasses like Rhodes, CoFS-29. Legumonus fodders like Hedge lucerne, lucerne, Groundnut and leguminous trees like Sesbania, Leucaena, Gliricidia, Moringa etc., the roughage should be chaffed to a fine chaff size of less than 1 cm, mix grass and legume at 70:30 ratio to optimize rumen fermentation for optimum performance in small ruminants.

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Chapter 7

APPLICATION OF SMART TECHNOLOGIES AS SUSTAINABLE STRATEGY IN MODERN SWINE PRODUCTION

Dr. Prasanna, S. B.
Associate Professor
Dept. of Livestock Production Management,
Veterinary College, Gadag-582101
Email: prasannalpm@gmail.com

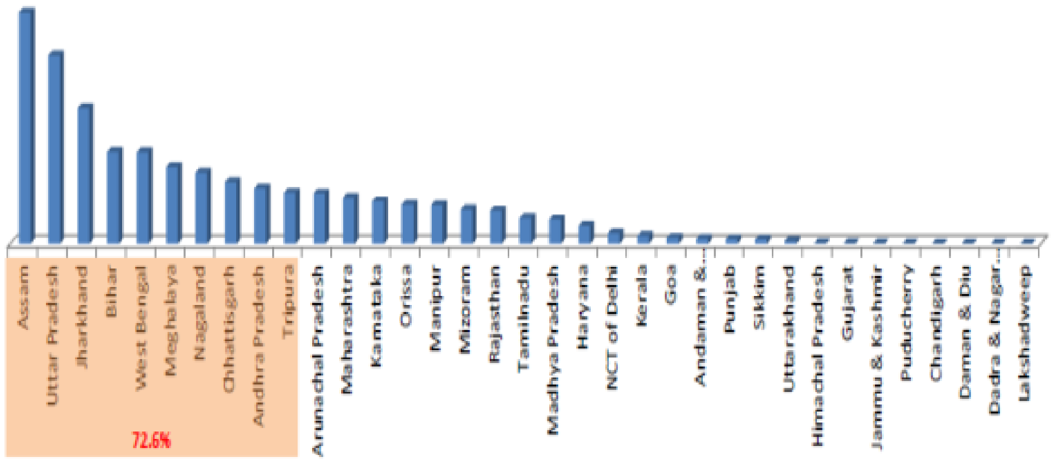
Introduction

Pigs are the most efficient domestic animals in converting the feedstuff and household / agricultural wastes into edible meat. Their contribution to the total meat production is reasonably good. Indigenous pigs produce the cheapest meat among all meat animals. Pork meat is the meat with the second-largest overall consumption, and chicken, pork, and beef together account for 92% of global meat production. Therefore, it is necessary to adopt more progressive methodologies such as precision livestock farming (PLF) rather than traditional farming methods such as uncontrolled environmental/microclimate, non-precision practices to improve production. According to 20th Livestock Census in 2019, the pig population in India was 9.06 million which is a decline of 12% over previous census 10.3 million (2012).

Piggery sector and Meat production:

The piggery sector in India is gaining slow but steady momentum. Owing to their fecundity, early maturity, and short generation interval, pigs are an ideal animal for intensive farming. In addition, the initial investment and maintenance is minimal. The majority of the pig population in India is distributed along the central and north-eastern belt of the country. In 2019, Assam, at over two million, had the highest population of pigs in India. Most of the pork consumption is limited to north-eastern states like Assam and Nagaland. Consequently, the north-eastern region also ranks high in pork production volume.

1.3.5 Pig population in different States



The top pig producing states in India is indicated graphically

Demographics

In India Pig Farming sector is highly un-organised and some of the salient features are following

1. In India, 70% of the pig population is reared under traditional small holder, low-input demand driven production system, except for limited number of semi-commercial pig farms in Kerala, Punjab and Goa. The typical production system consists of a simple pigsty and feeding comprises locally available grains, vegetables and agricultural by-products along with kitchen waste.

2. Pork consumption being popular among select populations, improved pig husbandry programme and pig-based integrated fish farming have significantly contributed in the poverty alleviation strategies of the Government.

3. Distribution of pig population across the country is not uniform, for instance, thick population of pigs is recorded in the eastern (2.8 million) and north-eastern (4.5 million) states; highest population is in Asom (2 million), followed by Uttar Pradesh (1.35 million), West Bengal (0.82 million), Jharkhand (0.73 million) and Nagaland (0.70 million). Most of

the pig population is again in the tribal belts of the country where the people are non-vegetarian.

4. Breeding Level: Over 20% of the pigs kept in India are crossed with exotic breeds, but with a large amount of inbreeding because of non-systematic breeding and selection. In nutshell, the pig rearing is still unorganized venture that requires science and technology driven support to make it a vibrant enterprise.

The total meat production in the country is 9.29 million tonnes. India ranks 8th in the world in terms of total meat production (Source: FAO). The meat production has increased by 5.62% as compared to previous year. The meat production from poultry is 4.78million tonnes, contributing about 51.44% of total meat production. The growth of poultry meat production has increased by 6.86% over previous year. The top 5 meat producing States are Maharashtra (12.25%), Uttar Pradesh (12.14%), West Bengal (11.63%), Andhra Pradesh (11.04%) and Telangana (10.82%). They together contribute 57.86% of total meat production in the country. The per capita availability reached at **6.82 Kg/Annum the year 2021-22,** a 0.29-point jump from 6.52 Kg/Annum of the previous year 2020-21. Nearly 51.44% of meat production is contributed by Poultry. Buffalo, Goat, Sheep, **Pig**, and Cattle contributes nearly 17.49%, 13.63%, 10.33%, **3.93%** and 3.18% of meat production respectively to the total meat production of the country. The largest meat producing State is Maharashtra that produces 12.25% of the total meat produced in the country followed by Uttar Pradesh that produces 12.14% of the total meat production. West Bengal is the third largest meat producing state in the country that produces nearly 11.63% of the total meat production in the country

Gap Analysis of pork production

The per capita consumption of meat in developed/industrialized countries is much higher compared with developing countries. Consumption of meat in the USA is 124 kg per capita per year (340 g/day). The global average meat consumption is 38 kg per year (104 g/day).Countries whose population consumes the least amount of meat are located in Africa and Asia. India's per capita meat availability being only 6.82 kg per year. Thus, it is apparent that there exists a huge gap of meat availability between India and the global average of 38 kg per year.

Advantages of Pig Farming

In comparison to other livestock species, pig rearing has higher potential for small and marginal farmers or rural poor due to following advantages:

1. Better feed conversion efficiency of pigs i.e., they attain more unit weight gain per kg of feed consumed as compared to other meat producing animals except broilers. They produce more live weight gain than other class of livestock.
2. Higher fecundity in pigs – Sows produce 6 - 12 piglets in each farrowing on an average. Pigs are prolific breeders, grow rapidly, mature quickly and can be managed to produce more than two litters in a year.
3. Pigs reach sexual maturity at an early age and can be bred as early as 8 - 9 months of age and can farrow twice in a year under optimal management conditions.
4. Pigs have shorter generation interval as compared to other classes of farm animals.
5. Offers quick returns since the market weight of 60-90 kg can be achieved in a period of 7-10 months.
6. One of the few farm animals where nearly all parts of the animal can be consumed by the farm family and/or sold.
7. Converts damaged feeds which are either not edible or not very palatable to human beings into valuable nutritious meat.
8. Apart from providing meat, it is also a source of bristles and manure.
9. Can survive and grow on wide variety of feed stuff viz. grains, vegetables, fruits, fodder, sugarcane byproducts, kitchen waste etc.
10. Offers employment opportunities to seasonally employed rural farmers and supplement income to improve their living standards.
11. Require little initial investment on building and pigs can be raised for their entire lifetime in enclosure as they do not contribute to loss of grazing lands
12. Pig products range from primary commodities such as pork, to processed food products such as sausages and smoked hams to cooked salted ears, eaten as snack foods.
13. Pig's fat can be used in poultry feed, soap, paints and other chemical industries.
14. Pig farming creates profitable work for the available Labouré on the farm, as it can be successfully combined with dairy or other agricultural activity.

15. Pigs utilize the waste products very efficiently. Table garbage, bakery waste, hotel and kitchen waste and unmarketable fruits and vegetables can be fed to pigs.
16. Pigs aid in maintaining soil fertility. They produce the feces which can be converted into good biological manure.
17. The pig production has a special significance in the northeastern region, where every family rear pigs and they use pork as staple food.

Pig production systems

The productive performance of pigs, as an indicator of business profit, depends on various housing conditions. Commercial pigs encounter many stress factors, including stocking densities, limited possibilities of movement, handling by the producer, unbalanced temperature, humidity, CO2, NH3 inside the shed, etc. Weaning is a critical stage of commercial pig farming. Nutritional, physiological, immunological, and psychological disruptions of nursery pigs due to poor management systems resulting in reduced feed intake, increased incidence of diarrhoea, loss of bodyweight, and higher mortality. Pig production systems are defined as all subsistence or commercial production systems where the purpose of the operation includes some or all of the breeding, rearing and management of pigs intended for meat production. Different pig production systems that are prevalent in India are:

1. Scavenging / nomadic system / extensive system
2. Semi intensive / semi-extensive system
3. Small scale indoor housing
4. Intensive system
5. Integrated system

Breeds of Pigs

In India there are 158 pig breeding farms are in Government sector in different parts of the country, catering the need of the 8 bacon factories in Government sector and 150 pig processing units in private sector. Majority of pigs in India are indigenous

There are 13 indigenous breeds of pigs registered by NBAGR as of 2023 viz.,

S.N.	Breed	Home Tract	Accession Number
1	Nicobari	Andaman & Nicobar	INDIA_PIG_3300_NICOBARI_09005
2	Doom	Assam	INDIA_PIG_0200_DOOM_09006
3	Purnea	Bihar and Jharkhand	INDIA_PIG_0325_PURNEA_09010
4	Agonda Goan	Goa	INDIA_PIG_3500_AGONDAGOAN_09003
5	Banda	Jharkhand	INDIA_PIG_2500_BANDA_09011
6	Manipuri Black	Manipur	INDIA_PIG_1200_MANIPURIBLACK_09012
7	Niang Megha	Meghalaya	INDIA_PIG_1300_NIANGMEGHA_09002
8	Wak Chambil	Meghalaya	INDIA_PIG_1300_WAKCHAMBIL_09013
9	Zovawk	Mizoram	INDIA_PIG_2700_ZOVAWK_09007
10	Tenyi Vo	Nagaland	INDIA_PIG_1400_TENYIVO_09004
11	Mali	Tripura	INDIA_PIG_1900_MALI_09009
12	Ghurrah	Uttar Pradesh	INDIA_PIG_2000_GHURRAH_09008
13	Ghoongroo	West Bengal	INDIA_PIG_2100_GHOONGROO_09001

These government pig breeding farms are maintaining the exotic stock of Large White Yorkshire, Middle White Yorkshire, Berkshire, Hampshire, Landrace, Tamworth etc. The government strategy in piggery development work is to use improved exotic pigs for grading up of the indigenous stock.

(a) Large White Yorkshire: It is the most extensively used exotic breed in India. White coat colour with occasional black pigmented spots, erect ears, snout of medium length and dished face are the typical characteristics of this breed. Mature body weight ranges from 300 to 500 kg.

(b) Middle White Yorkshire: Typical characteristics of this breed include white coat colour, long muscular neck and long back with a mature body ranging from 270 to 360 kg.

(c) Landrace: Pigs of this breed are typically white coloured with black skin spots. They have a long body, large drooping ears and long snout. Mature body weight ranges from 250- 350 kg.

(d) Berkshire: Black coloured animals with white patches on feet, snout and tail. Small head, erect ears, face depressed in middle and saucer shaped body with flexible ribs are typical characteristics of this breed. Mature body weight ranges from 280-350 kg.

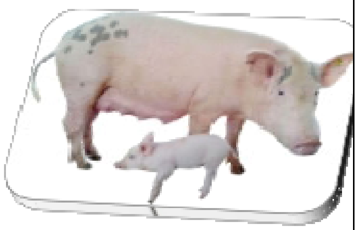
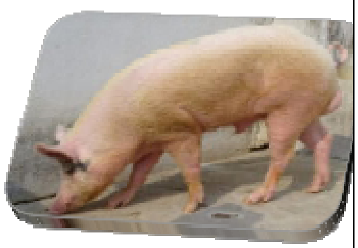
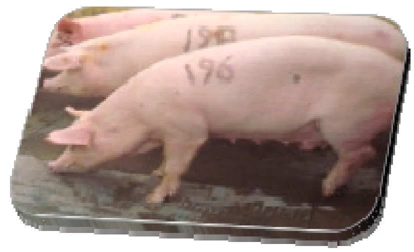
(e) Hampshire: Animals are black with white strip across forelegs to shoulder. Typical characteristics include small and erect ears, small and compact body. Sows have good mothering ability.

Crossbreds

All India Coordinated Research Project (AICRP) on Pigs which was started in 1970 has developed pigs of the following genotypes/genetic groups (Fig. 4.2):

- Improved indigenous pigs
- Crossbreds having 50:50 inheritance from Landrace and indigenous pigs
- Large White Yorkshire crossbreds having 50% indigenous inheritance
- Crossbreds having 75% Large White Yorkshire and 25% indigenous inheritance
- Landrace crossbreds having 25% indigenous inheritance
- Hampshire crossbreds carrying 25% and 50% indigenous inheritance
- Landrace X indigenous half-breds from reciprocal crosses

Presently, AICRP centers on Pigs follow a breeding plan to maintain crossbred animals of 75% exotic inheritance. Mega Seed Project on Pig and AICRP on Pig implemented by the National Research Centre on Pig enabled regular supply of good quality pig germplasm and location-specific research on pig nutrition and breeding throughout India

 TANUVAS KPM Gold	 HDK 75	 Jharsuk
 SVVU T17	 Mannuthy White	 Landlly
Crossbred varieties developed by AICRP on Pigs		

WHAT IS SMART TECHNOLOGY

Smart' technology refers to the integration of computing and telecommunication technology into other technologies that did not previously have such capabilities. What makes a technology 'smart' is its ability to communicate and work with other networked technologies, and through this ability to allow automated or adaptive functionality as well as remote accessibility or operation from anywhere.

Importance of Smart Swine Farming

According to the report of the FAO and the UN, compared with the current population (7.3 billion) and the food production level, about 50–60% more food will be needed for to provide for the increase in the population, which is estimated to be 33% higher (9.7 billion) by the year 2050. The technologies, such as sensors, robots, remote monitoring, weather satellites, etc. have opened a door of innovation in the farming system. New technologies include Internet of Things (IoT), ICT, big data, and robotics that enable industry to increase the farm operational efficiency by lowering costs, reducing waste, and improving product quality

How does it work?

Essentially, the 'smart' components are computing, sensing, and telecommunication technologies that have become so small, effective, and affordable that there are very few obstacles to their integration into existing devices, buildings, and infrastructures. As integration continues, more data collection points are added and so more information is collected and shared than was previously possible. Smart technology is also called as Precision Livestock Farming

The essential components are:

1. Sensors - The ability to collect data such as measurements, images, sounds, etc.
2. Microprocessors - The ability to manage sensor functions, data collection, communications, adaptive functionality, etc.
3. Memory - The ability to store collected data or received data.
4. Telemetry - The ability to send collected data or receive data from other sources, especially via wireless communication.

In pig farms in India practice traditional farming methods wherein expensive human resources monitor the animals. The health and welfare of animals continue to be the primary goal of farms. Watching the boundaries and training the animals can be affordable using humans, but in terms of welfare, human monitoring is limited to identification with the naked eye; therefore, it is expensive and can miss key indicators. For instance, the body temperature of an animal is a reproduction activity measurement, and temperature regulation is an important way to maintain the homeostasis of the animals. Measuring rectal temperature is a well-known technique for calculating animals' body temperature; furthermore, the respiration rate and heart rate are also monitored according to human resource availability. Such methods are very labor intensive, but technological developments could reduce the human workload involved. When attempting to measure temperature using technology rather than traditional methods, temperature-sensing ear tags (which can also be used to detect heat stress), wearable and implantable devices, thermal imaging cameras, IR sensors, etc., can be used but thus far have been used very limited way.

Precision Livestock Farming (PLF) system:

(a) Is a support tool and does not intend on replacing the farmer,

(b) Is an animal-centric tool – the animal is the main part of the process

(c) Needs ideal conditions for the monitoring and control processes.

In this century, when technology use is at an all-time high, more than 50% of farmers in India use the Internet and not just smartphones. Precision Livestock Farming has advanced in recent years due to the emergence of advanced technologies such as affordable **sensors, actuators, microprocessors, IoT-based monitoring systems, and big data analytics**. In recent years, PLF for pigs has been in high demand due to an increase in mortality rate at every stage of the lifespan due to environmental effects on piglets and health issues such as heat stress, breathing problems, etc., that occur more often in the growing stage. Consequently, welfare assessment within all phases of swine production is mandatory to produce desirable outcomes. Moreover, consumers also demand a higher welfare environment for sows and piglets in food production as standard practice. The following are the advantages of PLF adaptation over traditional farming practices.

1. Efficiency—sustainably utilizing resources by reducing waste (feed and water intake and waste could be monitored using cameras, flow meters, feed scales, etc.
2. Early disease detection—diagnosis of activity changes using cameras with the help of software, disease detection using welfare parameters (heat stress assessed by cameras, accelerometers, IR sensors [4,14], etc.), and improvement of animal welfare (Tail biting, fighting, etc.)
3. Environmental management—protect the animals from environmental stressors (PLF could regulate environmental stressors such as temperature, humidity, airflow, ventilation, etc.)
4. Performance—the workload of the animals can be reduced, or they can be subjected to external stress due to human activity inside the pen.
5. Information and individual monitoring—maximum data could be stored in a computer, which could be used to further visualize the situation (feeding efficiency can be calculated by collecting data of feed intake and the weight of the pigs
6. Body surface temperature data can be used to track heat stress.

7. All the data, including on physical movement, performance, biological information, phonotype properties, etc., can be used to visualize not only group- or house-level data but individual data, too
8. Analyzing ability—with big data, it is possible to produce advanced-level software to notify farmers about standard criteria.

Tools of Smart Technologies

Smart swine-farming technology is urgently needed to avoid unnecessary stress of pigs reared in conventional methods caused by handling while being fed, taken care of, and monitored. Applications of smart tools in modern swine industry:

Sl no	Name of smart tool	Uses
1	Radio Frequency Identification (RFID)	Identification of pigs, individual animal data, date of birth, mortality, pen number, farm number or group number, etc.
2	Infrared thermal imaging	Temperature of individual pigs or whole herd, muscle injuries, infectious disease, ovulation etc.
3	Microphone/cough de-tector/sound detector	Detection of normal or abnormal sound for sickness, coughing sound, heat detection, group behavior of pigs
4	ZigBee technology	To detect environmental parameters: temperature, relative humidity, concentrations of carbon dioxide and ammonia in pig house
5	Deep learning/image analysis	Auto locomotion, movement pattern, behaviour, posture, tail biting, temperature, body weight, etc
6	Two-dimensional (2D) cameras	Feeding time, body weight, posture, lameness, injuries, group behaviour, etc.
7	Three-dimensional (3D) cameras	Feeding time, body weight, posture, lameness, injuries, group behavior, etc.

8	Accelerometer	Pigs' movement pattern including standing time, posture, monitoring, and welfare, etc. Accelerometers are devices that measure the vibration, or acceleration of motion of a structure.

1. Camera-based monitoring for PLF

Cameras are ubiquitous tools for science and have been accessible worldwide at an affordable price for at least the last two decades. There are many types of cameras, such as CC cameras, infrared cameras, depth cameras, etc., available on the market; each type of camera offers different information and image parameters. A Closed Circuit (CC) camera can capture two-dimensional (2D) color images of an object, which can be used for further analysis. Those images give information on color (RGB), texture, shape, width , height, pixel values, etc., in a numerical form.

The RGB color band (red, green, and blue) can also produce gray, hue, saturation, and intensity factors by using image-processing techniques. **Feature extraction** is the next step for image processing: extracting the information, as mentioned earlier, according to particular needs. For instance, pixel values can correlate with real-time measurements of a pig to develop a simple program to find the length of pigs without measuring another pig's length. Likewise, finding out the weight, girth, height, and other body information of pigs using 2D images can easily be achieved using image-processing techniques.

Infrared cameras work on the same principle as typical RGB cameras; CCD cameras measure the radiation of visible bands; and thermal cameras detect characteristic near infrared radiation (0.75–1.4 µm (micrometres)) and thermal radiation (8–15 µm). Initially, **thermal imaging systems** were used in the oil and gas industries, pharma industries, for defense purposes, etc.; later on, they were adapted to find the temperature of animals. Since pigs are homoeothermic animals, they emit heat through temperature variations that can be identified quickly using thermal images. Unlike CC and depth cameras, thermal cameras are expensive; still, early detection is an important way to be aware of diseases and could be possible with thermal images.

An Overview of Software Used to Analyze an Image or Video: The core of camera-based technologies is software; cameras can only capture images, whereas software can interpret the data for image-based studies. Therefore, basic knowledge of the software used for the camera-based studies provides a better understanding of the process.

2. Auto Identification of Pigs : RFID and Cameras

A wide range of methods for the identification of livestock has been utilized so far. Techniques such as ear clipping, ear notching, ear tagging, microchipping, electronic identification devices (EID), and numbering or marking on pig skin have been practiced. An EID principled radio frequency identifier (RFID) is popular for identifying pigs. RFID is an advanced version of numbered ear tags, and passive electronic tags consist of a radio frequency identifier (RFID) that emits a signal to the reader through a microchip and a coiled copper antenna. A radio-frequency identification (RFID) technique has been applied in smart swine farming where the RFID tags can be attached or inserted into the animal's body (BASE OF EAR) to receive the health and behavior data from an individual or from the whole herd. Low frequency (LF: 125 kHz or 134.2 kHz), high frequency (HF: 13.56 MHz), and ultra-high frequency (UHF: 860–960 MHz) are the three primary frequency ranges in RFID systems. Even though RFID has advantages such as a simple mechanism, low cost, and reliable correlations for identifying objects, they have many disadvantages such as

1. Limited Range: RFID has a limited range (even long-range readers state a maximum distance of 120 cm) at which the tags can be activated and read successfully . In addition, multiple tags cannot be read concurrently; therefore, the data may not be reliable since pigs are playful and bunch together.

2. Readability: Ear-tagged RFID can become illegible for reasons such as wear and tear, breakage, and soiling.

3. Loss: Tags may be lost due to ear tearing during fighting or playing [39]. This is possible since the pig barn has metal objects; in addition, pigs are playful with plastic objects. In addition, the RFID tags are often exposed to harsh environments with excessive dirt, dust, and moisture, and they must function in extreme heat and cold, from −30 ◦C to 70 ◦C.

4. Welfare: Poor application of RFID could result in infection or ear damage. In addition, ear tags can be transferred from one animal to another, which increases infection possibilities. Hence face detection Cameras are more useful than RFID systems

3. Live Weight Detection Automatic Weight Detection

As a part of precision livestock farming, automated weight monitoring of pigs can be performed using image analysis as a smart tool in modern pig farming. Live weight is crucial for rearing pigs since the livelihood of farmers revolves around the weight of the animals. Studies indicate that the cost of feeding a pig is 75% or more of the total production cost. Periodic monitoring of pig weight is essential to optimize these costs since food intake and weight gain are linearly correlated and underfeeding or overfeeding issues could be revealed through this process. Monitoring live weight is not only due to the uncertainty in feeding; it is an index for evaluating the quality of reproduction and the rate of growth , the reproductive period , feed conversion efficiency, and disease occurrence. In addition, profit and loss accounts can be evaluated using the live weight concerning current market conditions.

Initially, the weight of pigs was assessed through observation by experts using eyes and hands, weight bands, electronic weighing platforms. But they are not considered an optimal way for pig producers to find the live weight. Alternatively, indirect methods such as calculating the body weight from the body dimensions (length and girth) were introduced in earlier studies. However, such a mechanism also required human resources and thus, may cause stress to humans and pigs, since pigs are sensitive to human handling.

In 1990, Schofield implemented the **indirect method** by using a non-destructive method, **a camera**. That author captured images of a pig from side view and top view (using a mirror placed 45◦ perpendicular to the pen); he extracted information of length (tail to scapula), girth, height at back and shoulder, and width from 15 pigs (the same pig was captured at 30–80 kg). His study predicted the live pig weight by correlating all the features with a ±6.2% error rate. Subsequently, 3D-based depth cameras were employed to monitor the live weight and weight gain through a fully automatic system. In addition, several products are available on the market to estimate individual weight using cameras through a mobile application or a computer. There are many weight solution products on the market. It is reported that the accuracy rate of fattening pigs' weight was about 97.5% (0.82 kg errors) at group level and 96.2% at an individual level (1.23 kg errors) through image analysis on a real-time basis. The device connected to a camera contains image-processing software that generates weigh data for a group of pigs or individual pigs. Machine learning technology MLT-based prediction is the most way to estimate the growth performance of pigs.

4. Growth Patterns and Body Condition Scoring of Pigs

As mentioned above, body morphology is not only an indicator of body weight; additionally, it acts as an indicator of other critical measures such as consistency in growth, weakness in legs , carcass traits , and the health and welfare of pigs. Therefore, the mass and volume of pigs is measured by the same morphological parameters used to detect the live weight. Furthermore, to assess the quality of the carcass, backbones and side ribs are also considered. Generally, a set of scoring categories, 1–5, is followed by carcass assessors based on the detection of ribs, backbone, H-bones, and pin-bones. The score details are as follows:

1: Emaciated—Obvious detection of ribs and other bones;

2: Thin—Easy detection of ribs and other bones while applying pressure;

3: Ideal—Ribs and other bones barely detectable while applying pressure;

4: Fat—No detection of ribs and other bones; and
5: Overly fat—No detection of ribs and other bones.

Thus, using this software, one can acquire body length, hip width, hip height, and heart girth information from pigs.

5. Remotely Monitoring Behavior (Feeding) and Welfare of Pigs :Study of Ethogram /behaviour of pigs

The study of the movement, behavior, and activities of pigs leads to their improved livelihood. The first step in tracking behavior is to identify an individual pig from the herd. The behaviours that need attention are aggression, posture and locomotion. Through the remote monitoring system, the swine farm owners can manage multiple sheds with minimum time and can obtain data from each shed or from individual pigs. Camera-based computer vision techniques have proven to be a more promising solution for identifying a pig from a group. Pigs are diurnal animals by nature, spending 93% of the night asleep. They lie down for an average of 86% of the day. Therefore, the lying-down posture of a pig is a critical factor, while other postures may be a sign of discomfort.

6. Detecting Locomotion and Lameness

Locomotion is generally defined as the walking movement of pigs, whereas failure of locomotion is called lameness. Locomotion tracking is similar to posture detection, but the categories would be measured in motion. Abnormality in locomotion is considered lameness, whether induced by the housing system, floor type, hygiene factors, genetics, toe or dewclaw management, or nutritional scarcity

7. Detecting Aggressive Behaviours

Pigs are social animals by nature, but their behavior is based on hierarchy while living in a group house. Aggression is a part of social order that typically happens during the mixing of animals with an unfamiliar group. Commonly, aggression type is divided into two groups: medium aggression (head to-head knocking, head-to-body knocking, parallel pressing, inverse parallel pressing, and fleeing), and high aggression (neck biting, body biting, and ear biting).

8. Detecting Tail Biting

Tail biting is an acute problem in pig farming; it causes severe damage to animal welfare and production quality. It causes stress due to pain but may also generate infection in the organs through wounds. Moreover, such conditions lead to partial or total contamination of the carcass quality, a vital parameter for economic aspects. The chances of tail biting in group-housed pigs are around 70% if the tail is visible. Tail docking has been considered the standard solution for the last five decades to avoid tail biting. However, even though tail docking decreases tail biting, it is not totally effective.

9. Eating and Drinking Solutions

Food and water are the primary necessities for living organisms. Unlike outdoor livestock, indoor livestock animals are unconditionally dependent on their farm owners for food and water. Numerous studies have shown that the growth rate is significantly affected if both are not available in the right proportions. Without proper nutrition, the animals can become depressed and are vulnerable to outbursts such as fighting among themselves. Non-nutritive visits (NNV) cause disputes among group-housed pigs. Pigs frequently visit the feeding area without consuming any feed, which may tempt others to rush to the feeding place. They considered a sow to be feeding if she was moving her head in the feeder with an up and down movement. That study not only identified feeding; it also identified lying, sitting, standing, kneeling, feeding, drinking, moving, and shifting, with exceptional accuracy.

10. Smart Technology on Monitoring the Health /Reproduction state of Pigs- Early Disease Detection at a Farm Level

Early disease detection is a practice to reduce the mortality rate through illness or infection. Generally, any infection causes weakness, fever, and progressive deceleration of diurnal activities. Monitoring activities such as drinking, eating, lying, and walking is significant, and changes in activities are a way to track animal health. We have already discussed the identification and tracking of the behaviours of pigs; another significant indicator is the **temperature of the pig's body surface or parts**. Since most infections cause a fever, body temperature fluctuation is an easy way to identify the diseases. The body temperature of pigs is variable in different body parts; each part, e.g., the eyes, nose, and legs, has a different normal temperature level. **Finding the temperature using infrared thermographic** images is a successful method that has recently become standard. The accuracy of this image-analyzing technique is for measuring temperatures up to 0.08◦C. In addition, this technique is completely non-invasive and has no risk of spreading diseases. Furthermore, the vulval temperature by infrared thermography can provide necessary information of ovulation in sows.

Sweat glands are the temperature regulators for human beings, whereas pigs have no sweat glands to regulate the body temperature. Since disease causes an increase in the body temperature of pigs, infrared thermographic imagining (IRI) is an effective method to be aware of the temperature. 2D cameras are often employed for early disease detection; a lethargy detection study using computer vision techniques. Disease decreases the regular activity of pigs; accordingly, it is considered lethargy is a way to identify African swine fever (ASF).

11. Pig Cough and Sound surveillance analysis

Real time monitoring of farm and health status of pigs can be achieved not only by video image analysis but also with sound analysis techniques. Vocalisations and screams are behavioural expressions among pigs that convey information about their current health and welfare status. This information can be of extreme help for the farmer in early problem detection and disease outbreaks or aggressiveness escalation prevention. Many researchers have found that vocalization analysis in pigs can help identify both pain and behavioral changes indicating that a system that combines both **camera-based and audio analysis system** could potentially improve contemporary PLF systems. Therefore, a PLF tool that analyses pigs' vocal behaviors and automatically detects pain could potentially be built, providing the farmer with an early warning signal and/or helping for an early solution, prior to the conflict escalation.

Cough sound analysis can assist not only in monitoring pigs' health status but also in the early detection of various respiratory diseases. Some scientists developed a model that automatically analyses pigs 'cough sounds and provides information of air quality (i.e., temperature, humidity, ammonia concentration and dust concentration) at room level, with a 95% average recognition percentage. Sound sensors surveillance and sound data analysis in pigs helps in Cough and screams monitoring/ analysis and diseases detection, Feeding control, Identification of age, sex and stress, Air quality, Stress detection, Pain detection etc. The duration and intensity of screams are better stress indicators than the actual number of screams. Sound analysis is feasible and it will be an essential part of future PLF systems. As an output of continuous research on sound analysis, now it is possible to identify the sick pigs 2-12 days before the conventional farm diagnosis by farmers or veterinarians

Table 1. Summary of 2D and 3D camera algorithms used for precision pig farming

Information Communication Technology (ICT) sensors – combined systems

Various sensors have been used to monitor various parameters of interest within a pig barn such as radio-frequency identification (RFID) chips and depth sensors along with more complex systems including neural networks analysis, electronic feeders, and drinkers. Research in this area usually refers in a combination of sensors and systems and most research have been conducted using sensors installed on electronic feeders. The series of related studies and research conducted in this area is presented in Table 2.

Table 2. Various equipment used for data analysis in pigs

PLF Systems	Area of focus
UHF-RFID data anlysis	Individual identification
	Feeding behaviour
	Drinking behaviour
	Oestrus, Lameness and health disorder detection
Accelerometers data analysis	Reproductive and respiratory disease syndrome virus detection
	Sows nesting behaviour duration detection
Environmental deta anlysis	Tail biting, diarrhoea and fouling detection

Other Smart Technologies on Swine Farm Management Practice

1. Recently, the application of a robotic system for cleaning, and sanitizing the floor or housing materials, is a great invention of modern technology to save time, labor and prevent zoonotic diseases originated from farmhouse or farm products. A robotic machine is an automatic high-pressure device that can move around and perform farm operations in pig houses
2. Similarly, the tasks (electric or CO2 stunning systems, carcass washing, scalding and dehairing, cutting parts, etc.) in a slaughterhouse can be automated by machinery or a robotic system to ensure the carcass is free from contamination, saving labor, time, money, etc.
3. How ever, further development of a robotic system is needed to make it smarter to perform its function so that it would be applicable in commercial farms with an affordable cost. In addition, the smart technologies (RFID, bar code, tags etc.) applied when packaging the farm products are also useful to obtain the information of shelf life, expiration date, preservation temp, and quality of product in smarter ways

Conclusions

The application of sensors (cameras, microphones, accelerometers, or radio-frequency identification transponders), the images, sounds, movements, and vital signs of animals are now the subject of scientific attention in modern swine farming to ensure the good health, welfare, and optimum production of pigs. The transition to digital, intelligent production technologies and robot-based systems is one of the priorities of the scientific and technological development of modern-day pig farmers. With the help of IoT technology, a device will be connected to the internet, resulting in easy decision making, and the farm can be operated automatically or remotely. Even though technological advancement is rapid, it is not surprising that there are limitations on any technology. Similar to other PLF technology, camera sensors have some limitations that affect their implementation in commercial farms. Such limitations need to be tackled by future researchers to improve the efficiency of PLF

The challenge for the country is to provide good quality protein to the population especially children and women, who should be kept away from hunger and malnutrition. Pig farming in India effectively covers the neglected sector, especially the tribe and members of marginalized community in terms of indigenous breeds of pigs with little or no support to promote themselves by the society as well as institutions. On the other side it attracts the rich who prefer delicacy in terms of exotic food besides frozen and canned foods. In this situation, it is imperative to enhance the production, productivity and quality in terms of clean pork for growth of the industry. The current review summarizes studies utilizing 2D/3D/Infrared cameras to acquire information on pigs. In the future, farmers will depend on AI algorithms for automatic monitoring, control, and overall management

Further reading

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Chapter 8
NEW TRENDS IN POULTRY NUTRITION

Dr. P. Vasan
Department of Animal Nutrition,
Veterinary College and Research Institute,
Namakkal, TANUVAS, Tamil Nadu

Introduction

Globally, poultry production is recognised as an important aspect of the animal agriculture. It's well known fact that the intensification and commercialization of the poultry sector is accelerated by research discoveries in the field of breeding, nutrition, housing management and disease control. These research efforts were largely targeted towards the following: improving genetic strains specialised for food (meat and eggs) and regional conditions; improving knowledge of nutritional requirements and ability to match these for variable conditions; and ensuring stable environment for growth and production. These research efforts are still on-going in the light of new challenges facing the poultry industry in terms of birds' welfare and issues of environmental pollution as well as consumers' concerns of food quality and safety.

Currently the biggest problem in poultry production is the cost factor. The animal nutrition sector faces serious problems with the supply of raw materials and pricing. The global situation of raw material shortage and sharp price increases is exceptional. Even though this situation will eventually normalize again, and prices will stabilize at reasonable levels, cost optimization is currently more important than ever.

New recommendations and regulations relating to poultry housing systems, quality of feeds and additives used in nutrition impose the need to find alternative solutions. The main objective of mentioned regulations is improvement of poultry housing conditions, birds' welfare and providing safe food (meat and eggs) for human consumption. In this pretext, poultry production should focus on adjusting to demand of customers by providing/ensuring quality poultry products (meat and eggs). This paper discusses the new trends and challenges confronting nutritional research in the 21st Century.

Poultry Housing and Feeding System

The recent rules and directives relating to housing system for layer birds banning the use of traditional battery type cages has made it imperative to identify alternative housing systems.

"Deep litter" system or modified cages where more space is provided for layers are recommended as alternative systems. Change in housing system also necessitates change in production technology, especially nutrition system. Layers housed in alternative systems have more possibilities for moving and also experience more changes in the environment temperature. All of this not only affects the amount of feed required but also the metabolic energy in the diet. It has been observed that the daily needs of feed for layers have increased by 10 g, while in those birds reared in free range system increased by 15 g per day. Basically, the feed consumption as well as feed conversion of layer birds housed in alternative systems is less favourable. Also mortality is higher in layers housed in alternative systems. The cost of production of eggs increases by at least 13% in layers housed in alternative systems which are mainly because of increased cost of labour and feed (Harne Van PLM, 2003).

Alternative housing systems are also recommended for fattening broiler chicken. One such system is "floor system". Even though this system enjoys certain advantages, considerable disadvantages are also experienced by the broiler birds. Microbial decomposition of litter leads to air contamination of the chicken house environment. During growth phase of broiler birds, the concentration of ammonium and dust in air increase. This has negative impact on growth traits viz., lower body weight gain, poor feed conversion efficiency and higher mortality (Homidan *et al*., 2003). In this pretext, the future efforts should focus on improving the housing conditions for broilers and layers without affecting the production and economic returns.

Optimising compound feeds for Nitrogen

Recent advances in poultry nutrition have focussed on three main aspects: i) developing an understanding of nutrient metabolism and nutrient requirements; ii) determining the supply and availability of nutrients in feed ingredients; and iii) formulating least-cost diets that bring nutrient requirements and nutrient supply together effectively. The overall aim is *precision feeding* to lower costs, minimize pollution and maximize economic efficiency.

Precision feeding is formulating the ration to meet the nutritional requirements of poultry. This concept is about doing the right thing, in the right place, in the right way, at the right time. Precision feeding is based on the fact that birds within a flock / farm differ from each other in terms of age, weight and production potential and therefore each have different nutrient requirements. Precision feeding involves the use of feeding techniques that allow the right amount of feed with the right composition to be provided at the right time to each bird in the farm. Precision feeding may be a powerful approach in reducing feeding costs and improving nutrient efficiency by reducing excesses of the most economically and environmentally detrimental nutrients without jeopardizing bird's performance. The essential elements for precision feeding include 1) the proper evaluation of the nutritional potential of feed ingredients, 2) the precise determination of nutrient requirements, 3) the formulation of balanced diets that limit the amount of excess nutrients, and 4) the concomitant adjustment of the dietary supply and concentration of nutrients to match the evaluated requirements of birds.

To begin precision feeding:

- Formulate rations based on amino acids instead of crude protein
- Select feeds with low nutrient variability
- Use "true amino acid digestibility" to formulate rations closer to amino acid requirements
- Include additives that reduce nitrogen excretion and enzymes that increase bird performance and diet utilization
- Avoid and control anti-nutritional factors that impede the bird's ability to absorb nutrients
- Select ingredients with readily available phosphorus

Precision nutrition entails formulating feed to meet more precisely the animals' nutritional requirements, causing more of the nutrients to be metabolized, thereby reducing the amount of nutrients excreted. For more precise feeding, it is imperative that both the nutritional requirements of the animal and the nutrient yield of the feed are fully understood. Greater understanding of poultry physiology has led to the development of computer growth models that take into account a variety of factors, including strain, sex, and age of bird, for use in implementing a nutritional program. By optimizing feeding regimes using simulation results, poultry operations can increase growth rates while reducing nutrient losses in manure.

In the past, there was a tendency to over-formulate diets when there was doubt about the availability of critical nutrients (especially amino acids and phosphorus) or when nutrient requirements were uncertain. This practice is no longer acceptable, not only because it is wasteful, but also because excess nutrients excreted in the manure are ultimately a source of pollution. Fine-tuning diets to closely match the requirements of the birds helps to optimize the efficiency of nutrient utilization. The major developments towards achieving the goal of precision feeding are discussed below.

Determining nutrient requirements

Defining nutrient needs is challenging because they are influenced by several factors and are subject to constant change. The factors influencing nutrient requirements are of two main types: bird related ones, such as genetics, sex, and type and stage of production; and external ones, such as thermal environment, stress and husbandry conditions. Precision in defining requirements requires accuracy in both areas. Great advances in the definition of nutrient requirements for various classes of poultry have been made possible largely by the increasing uniformity of genotypes, housing and husbandry practices throughout the poultry industry.

Determining requirements for the ten essential amino acids has been made easier by acceptance of the *ideal protein* concept. As for other nutrients, the requirements for amino acids are influenced by various factors, including genetics, sex, physiological status, environment and health status. However, most changes in amino acid requirements do not lead to changes in the relative proportion of the different amino acids. Thus actual changes in amino acid requirements can be expressed in relation to a balanced protein or ideal protein. The ideal protein concept uses lysine as the reference amino acid, and the requirements for other essential amino acids are set as percentages (or ratios) of the lysine requirement. Table 1 shows the ideal protein balances for meat chickens at different growth phases. The advantage of this system is that once the lysine requirements for a variety of conditions are determined, the needs for all other essential amino acids can be calculated. This approach has now become accepted practice for setting the amino acid specifications of feed formulations in the poultry industry.

Table 1 Ideal amino acid ratios of meat chickens for three growth periods

Amino acid	1–21 days	22–42 days	43–56 days
Lysine[1]	100	100	100
Arginine	105	108	108
Histidine	35	35	35
Isoleucine	67	69	69
Leucine	109	109	109
Methionine + cysteine	72	72	72
Phenylalanine + tyrosine	105	105	105
Threonine	67	68.5	68.5
Tryptophan	16	17	17
Valine	77	80	80

[1]Recommended digestible lysine requirements for meat chickens of 1 to 21, 22 to 42 and 43 to 56 days are 1.070, 0.865 and 0.745 per cent, respectively.

Estimating nutrient composition and feed ingredient quality

Poultry producers are continually looking for opportunities that allow more flexibility in both the types and the levels of feed ingredients for use in feed formulations. Such opportunities are becoming increasingly frequent because of advances in nutrient analysis and feed evaluation techniques.

The principal role of feed ingredients is to provide the nutrients that the bird digests and utilizes for productive functions. Currently, considerable data are available on the ability of raw materials to supply these nutrients. However, a degree of variability is inherent to each raw material, and this places pressure on precise feed formulations. Data on variation (or matrices) are available for the main feed ingredients and are applied in feed formulation programmes to achieve better precision. A related development is the availability of *rapid tests*, such as near-infrared reflectance analysis, to predict gross nutrient composition and assess the variability in ingredient supplies on an ongoing basis. It is recognized that not all the nutrients in ingredients are available for production purposes, and a portion of nutrients is excreted undigested or not utilized. As feed evaluation techniques develop, data have been accumulating on the availability of nutrients for poultry, especially of amino acids and phosphorus. For example, a recent development has been the wider use of *digestible amino acid* concentrations, rather than total amino acid concentrations, in feed formulations. The use of digestible amino acid content is particularly relevant in developing countries, where highly digestible conventional ingredients are not available and diet formulations may include ingredients of low digestibility. Formulating diets based on digestible amino acids makes it possible to increase the range of ingredients that can be used and the inclusion levels of alternative ingredients in poultry diets. This improves the precision of formulation, may lower feed costs, and ensures more predictable bird performance.

Feed Management Technologies

By targeting animal nutritional needs, precision feeding can reduce nutrients excreted in faeces or urine while maintaining or even improving animal production and the economic viability of an animal operation. Reducing the nutrients in manure lowers airborne emissions. Precision feeding managemental techniques include: separating animals according to nutritional needs and production potential, limiting excess nutrients, and improving the efficiency of nutrient absorption.

Phase and Split-Sex Feeding

Two types of animal separation practices are used for precision feeding: phase feeding and split-sex feeding. For phase feeding, animals are separated by age or production state (e.g., birds at different physiological stages), and diets (e.g., nutrients) are matched to the different nutritional needs of each phase. For split-sex feeding, animals are separated by sex, and diets (e.g., nutrients) are adjusted accordingly. Phase feeding is commonly used currently, but split-sex feeding is yet to be practised due to its practical difficulties. In case of broilers this type of feeding strategies is feasible.

Limiting Excess Nutrients

Excess nutrients not absorbed in the digestive tract are voided in the excreta. Dietary protein provides amino acids, nitrogen, sulphur, and other elements needed for reproduction, growth, and egg production. Birds use less than half of the nitrogen that they consume, with the remaining excreted in the faeces. Limiting crude protein levels in the diet to only that used by the bird limits nitrogen excreted in uric acid, which contributes to emissions. While reducing crude protein content will reduce nitrogen excretion and ammonia emissions, reductions in crude protein can severely impact bird's performance. To effectively reduce crude protein concentrations of diets for swine and poultry, additional supplementation of synthetic amino acids is needed. Birds require a specific profile (ratios) of available amino acids; thus, lowering crude protein levels requires supplementation with select amino acids that otherwise would be insufficient. Specific synthetic amino acids can be added to meet the nutritional needs of a bird according to genetic lines, age, sex, and other factors.

Research has shown that high-quality, protein-limited diets with appropriate supplementation of amino acids can effectively reduce nitrogen excretion and ammonia emissions from swine, poultry, and dairy and beef cattle operations without a loss in animal productivity. Commonly used amino acids are lysine, methionine, and threonine, which usually can be added to feed without additional costs (Applegate *et al*., 2008). Other amino acids are typically more expensive. In general, each 1 per cent reduction in crude protein with appropriate amino acids supplementation in poultry and swine diets results in approximately a 10 per cent decrease in nitrogen excretion. Greater reductions in ammonia emissions have been reported for swine and poultry fed reduced protein, amino acid-supplemented diets (Powers *et al.,* 2007).

Undesirable sulphurous compounds often originate from sulphur-containing amino acids and sulphur-containing mineral sources. Additionally, sulphur content of water supplies can impact the generation of undesirable sulphurous compounds. Limiting unnecessary sources of sulphur can reduce emissions of hydrogen sulphide and other volatile sulphur compounds.

If feeding costs and nutrient excretion are to be minimized, it is essential that the composition of the available feed ingredients, their nutritional potential and the birds' requirements be properly characterized and that the supply of dietary nutrients be accurately adjusted to match the requirements of the animals. For the feeding of a population, however, optimal feed composition is difficult to estimate, as the response of the population to rising concentrations of nutrients is affected by many factors, including genetics, gender and the environment as well as the variability between the individuals of the population to be fed.

Precision feeding significantly reduces the amount of nitrogen and phosphorus released into the environment. It also reduces ration costs and costs associated with manure management. Using a combination of several techniques, such as phase feeding, split-sex feeding, minimizing feed wastage, and targeting diets to specific genetic lines, can reduce ammonia and hydrogen sulphide emissions 30-50 per cent and odours by 30 per cent with little extra cost for the producer.

Optimising compound feeds for Trace Minerals

Trace minerals (TM) are essential in the diets of laying hens and plays a specific key role in the pathways of shell formation and egg production. Zinc (Zn) is a cofactor of carbonic anhydrase, which is essential for shell deposition (1). Manganese (Mn) is an activator of enzymes involved in the synthesis of glycosaminoglycans and glycoproteins, which are important in the formation of the organic matrix of the shell (2) and Copper (Cu) is an integral part of the lysyl oxidase that catalyzes the cross linking of collagen and elastin in the eggshell membrane [1-3].

As an industry practice, the diets of laying hens are typically supplied with TM in the form of inorganic compounds, i.e. oxides, sulfates, etc. However, inorganic (ITM) source interacts with dietary components forming insoluble complexes and reduces mineral availability. Consequently, ITM are usually provided in excess of the recommended amount to cover basic requirement and prevent deficiency. However, dietary minerals in excess of the requirements are excreted in the litter contributing to environmental pollution [4].

Stages in the Evolution of Mineral Nutrition for Animals

Stage	Approx.Dates	Description
1st Generation	1930's thru 1950's	Metal oxides & industrial by-products
2nd Generation	1950's thru 1980's	Shift to metal salts of sulphuric acid for Higher RBV
3rd Generation	1980's thru current	Metal salts of organic acids
4th Generation	1990's thru current	Basic metal salts of low-cost mineral acids

Hydroxy TM (HTM) is the newest and most technologically advanced form of TM with high bioavailability and low environmental impact. These TM is characterized by unique crystalline structure and low solubility, which promotes better stability in feed, improved bioavailability and increased efficacy. In contrast with oxide / sulphate inorganic sources, HTM do not go into solution nor disassociate early in the digestive tract resulting into more Cu, Zn and Mn being delivered for absorption and utilization in the lower intestinal tract.

Of late, several animal trials have focused on the supplementation of this new generation TM. The result of a trial in laying hens in which different sources and dosages of TM (HTM vs ITM) were evaluated showed that HTM decreased the percentage of cracked eggs, increased egg production and improved efficiency of laying [5].

Alternatives to antibiotics

Sub-therapeutic level of antibiotics are used as antibiotic growth promoters (AGPs) in broiler chicken diet over the past five decades to limit the proliferation of pathogenic microorganisms in the gut and thereby increase the feed efficiency. This has resulted in occurrence of antibiotic residues in poultry products and development of antibiotic resistance in human. Later, ban was imposed on use of antibiotics as growth promoters in poultry nutrition which led to marked reduction in poultry production. This negative effect of the ban on application of antibiotics in poultry nutrition was attempted to be alleviated by improved housing conditions, quality feed and water, management and poultry selection focusing on higher resistance to certain diseases (Wiebe Van Der Sluis, 2004). Besides these strategies, antibiotic replacers were introduced. Among the numerous alternatives like probiotics, prebiotics, acidifiers and phytobiotics, the plant origin compounds attracted more interest. Many plant extracts have proved to deliver multifaceted functions *viz.*, antimicrobial action, augmentation of immunity, antioxidant activity, gut microflora manipulation, nutrigenomic effects, digestibility enhancement, stress lowering as well as cholesterol-lowering effect (Prabakar *et al.*, 2016).

Antibiotic alternatives in Feed Efficiency of broilers: OMICS approach

Feed efficiency (FE) represents one of the most important and complex traits in poultry production, since up to 70% of total production cost are attributed to feed. Many efforts were made to understand the molecular aspects in different tissues of broiler chickens which may exert a huge effect on the overall expression of FE phenotype.

In chickens, muscle being one of the main metabolic organs, the bioenergetics processes within the muscle can deeply influence FE in broilers. As mitochondria are responsible for producing around 90% of the energy pool for cells, studies have been conducted to evaluate whether the expression of different FE phenotypes would be associated with differences or inefficiencies in muscle mitochondria structure and functionality. Gene level studies showed differences in the expression of genes involved in mitochondria biogenesis [peroxisome proliferator-activated receptor-γ (PPAR-γ), PPAR-γ coactivator-1α (PGC-1α) and inducible nitric oxide synthase (iNOS)] and energy metabolism [avian adenine nucleotide translocator (avANT), cytochrome oxidase III (COX III), and avian uncoupling protein (avUPC)] in breast muscle of birds revealing either high or low FE (Ojano-Dirain et al., 2007). Regarding the physiological aspects, the activity of mitochondria complexes I, II, III, and IV has been reported to be higher in breast muscle of high FE birds compared to low ones. Recently, the up-regulation of genes associated with electron transport chain (ETC) complex I, as well as the greater predicted activity of complex I, III, IV and V (Kong et al., 2011) in breast muscle of high FE birds, seem to confirm an overall increased activity of mitochondrial complexes in the high FE phenotype.

When breast muscle global mRNA expression was assessed using a microarray-based approach (Kong et al., 2011), high FE birds were characterized by an up-regulation of genes either involved in anabolic processes (protein packaging and scaffolding activity, purine and pyrimidine biosynthesis, prevention or delay of apoptosis and modulation of gene transcription), or related to major signal transduction and cascade mechanisms pathways [Protein kinase-A

(PKA), c-Jun NH(2)-terminal protein kinase (Jnk), retinoic acid and retinoid X receptor (RAR-RXR)] or in sensing the energy status and regulating energy production in the cell [Adenosine monophosphate AMP-activated protein kinase (AMPK) and protein kinase AMP-activated non-catalytic subunit gamma 2 (PRKAγ2)]. At the same time, high FE birds showed down-regulation of genes associated with cytoskeletal organization, as well as cyto-architecture and integrity-related genes, major histocompatibility complex cell recognition, stress-related heat shock proteins and several platelet derived growth factor genes. Of late, the biological basis of the differences between high and low FE chickens investigated through mRNA-seq and pathways analysis identified a total of 1,059 differentially expressed genes between high and low FE chickens. High FE birds had a greater expression of genes related to muscle development, hypertrophy and remodeling, as well as a decreased expression of protein degradation and atrophy-related genes. These results, associated with the predicted activation of growth hormone and insulin-like growth factor-I/phosphatidylinositol 3-kinase/protein kinase B (IGFs/PI3K/Akt) signaling pathways, might explain the higher breast yield observed in high FE birds.

Adipose tissue plays a central role in energy homeostasis being a metabolically active organ with endocrine and regulatory functions. Low FE chickens showed higher lipid accumulation, which was likely determined by the up-regulation of genes involved in lipid synthesis, as well as down-regulation of genes enhancing triglyceride hydrolysis and cholesterol transport from adipose tissue. The gut is also considered as one of the most important tissues able to influence the expression of different FE phenotypes due to its function in nutrient digestion and absorption, as well as for its immunological role. Ojano-Dirain et al. (2007) found a higher level of oxidized proteins in duodenal mucosa homogenate and duodenal mitochondria of low FE birds. On the other hand, higher mRNA expression of PPAR-γ and iNOS was observed in the duodenum of high FE birds, whereas no significant difference was reported for PGC-1α, avANT and COXIII.

The "omic" technology platform has the potential to relate complex mixtures to complex effects in the form of gene/protein expression profiles. By their nature, these technologies reveal unexplored properties of biological systems. Advances in "omics" technologies have the potential to revolutionize our approach to development of novel non-antibiotic (natural) growth promoters (NAGP). However, the promise of rapid advances in NAGPs "from the lab desk to the bird desk" has not manifested as of yet. In reality great progress has been made, however understanding processes such as antibiotic response and resistance requires systematic insight into dynamic differences in gene regulation, interaction and function. Although each of the analytical platforms provides very useful outputs, they are able to describe only a part of the entire biological picture if considered singularly. Each protein, regardless its role and form, expresses a function that assumes significance only in the context of all the other functions and activities also being expressed in the same cell. Therefore, the next step should be focussed to integrate all the information obtained by the different omics platforms using appropriate bioinformatics and statistical tools. This relatively new approach would provide a holistic overview of the entire biological system rather than its single component alone.

The new omics technologies seem set to fulfil huge expectations. However, it is necessary to further standardize and automate the methods of especially proteomics and metabolomics in order to make efficient and reproducible high-throughput analyses.

Use of novel feed ingredients

Traditionally birds are grain feeders; however, with advent of industrial processing of food for humans, a lot of by-products have been generated and research extensively for poultry feeding. These include cereal offals, oilseed meals, brewer's dried grains, distillers dried grain with solubles (DDGS), etc. Besides, through research, lesser used feedstuffs such as barley, rye, sorghum, cassava and grain legumes are increasingly being processed for feeding. Furthermore, other plant resources in the wild such as false yam and forages are being harnessed for feeding due to advances in feed processing technologies and analytical tools. The essence of using these novel feed ingredients is to serve as alternatives for conventional feed ingredients such as maize (*Zea mays*) and animal proteins (e.g. fishmeal, meat and bone meal). This is aimed at reducing feed cost or curtailing dependency.

Shortage of protein feed resources is the major challenge to the global poultry industry. Insects are known as an alternative protein source for poultry. A wide range of insects are available for use in poultry diets. Insect larvae thrive in manure, and organic waste, and produce antimicrobial peptides to protect themselves from microbial infections, and additionally these peptides might also be functional in poultry feed. The feed containing antimicrobial peptides can improve the growth performance, nutrient digestibility, intestinal health, and immune function in poultry. Insect meal contains a higher amount of essential amino acids compared to conventional feedstuffs. Black soldier fly, mealworm, housefly, cricket/Grasshopper/Locust (*Orthoptera*), silkworm, and earthworm are the commonly used insect meals in broiler and laying hen diets.

Black soldier fly meal (BSFM) is a good source of protein, and energy, enriched with essential, and nonessential amino acids, saturated, monounsaturated, and polyunsaturated fatty acids (PUFA), vitamins, and minerals. The concentration of crude protein (CP) in BSFM ranged from 35% to 61%. Black soldier fly contains higher concentrations of lauric acid and palmitic acid. The concentration of crude fat in BSFM ranged from 7% to 42%. Methionine content in BSFM ranged from 0.08% to 0.90%. However, methionine + cysteine is 1.30%. The concentration of lysine ranged from 0.34% to 3.30%, and threonine ranged from 0.22% to 2.26%. Black soldier fly larvae contain 3 to 10 times higher calcium and magnesium content than other insects (Oonincx, 2015). The concentrations of calcium and phosphorus in BSFM ranged from 1.21% to 4.39%, and 0.74% to 0.95% respectively. Considerable studies showed that BSFM is the superior insect protein to improve growth performance, carcass composition, and meat quality in broiler chickens.

Mealworms are the brown worm-like larvae of the darkling beetles. Mealworms can be found throughout most of the world where they prefer warm, dark, and damp places like under decaying logs and leaves. Mealworms are designed for burrowing and eating and will feast upon the grains, vegetation, spoiled food, and many other types of fresh or decaying organic matter. The concentration of CP in MWM ranged from 27% to 54%, and fat ranged from 4% to 34%. Broiler chickens fed on the diet containing MWM have better disease resistance and immune responses due to prebiotic effect of chitin (Bovera *et al*., 2015).

The House Fly can be found in all countries and in any climates. It is commonly associated with animal faeces and can be found feeding on animal manure and food wastes. The concentration of CP in HF meal (HFM) ranged from 40% to 64%, and crude fat in HFM ranged from 2.5% to 28%. The older HF larvae contain less CP and more lipids than young HF larvae. The amino acid profile of HFM is comparable to fish meal, most limiting amino acids, lysine and methionine are in higher concentration. Insect processing method could also influence the nutritional profile of the insect meal. Housefly meal can be used as a substitute for fish meal or soybean meal, and HFM can improve the production performance (Khan *et al*., 2018) and meat quality of broilers at different concentrations

Cricket/Grasshopper/Locust (*Orthoptera*) meal (OTM) is a rich source of protein, amino acids, fatty acids, minerals, and vitamins. The concentration of CP ranged from 48% to 65% and crude fat ranged from 3% to 21%. Short horned grasshopper (*Oxya hyla hyla*) contains about 64.67% CP, 2.58% crude fat, desert locust (*Schistocerca gregaria*) contains about 50.9% CP and 20.5% crude fat, and wild edible grasshopper (*Ruspolia nitidual*) contains about 52% CP and 21.4% crude fat. Chinese grasshopper (*Acrida cinerea*) contains about 65.4% CP and 8.3% crude fat. Arbor Acres broiler chickens fed on the diet containing 50% (5% in diet) or 100% (10% in diet) grasshopper meal as fish meal replacer exhibited improved growth (Brah *et al.,* 2017). Grasshopper meal completely and successfully replaced fish meal in the diet of Anak 2000 broiler chickens without any effect (Sanusi *et al*., 2013).

Silkworm meal is a good source of protein, fatty acids, amino acids, minerals and vitamins. Silkworm contains about 71.9% CP, 45.87% for spun silkworm pupae and 50.31% for reeling silkworm pupae. Silkworm chitin which is a component of exoskeleton, contains approximately 25% CP, it does not contain amino acids and is not digestible. The reported values for fat are 20.1% for silkworm pupae meal, 7.94% for spun silkworm pupae and 25.76% for reeling silkworm pupae. Silkworm meal successfully substituted for fish meal or soybean meal in the diet of broiler chickens with no significant effect. Soybean meal was also successfully and completely replaced by SWM in the diet of white leg horn hens without any effect.

Earthworm meal (EWM) is rich source of protein, energy, and amino acids. The concentration of CP in EWM ranged from 41% to 66%, and crude fat ranged from 3.5% to 18%. It is generally believed that the CP content in earthworms is between 50% and 70%, and the crude fat content is less than 20%, and its content is related to the freshness and dryness of the earthworms. In addition, EW products are often used in poultry feed in the form of EWM or a mixture of EWM and vermi-humus. Feeding broilers with feed supplemented with 1% EWM and 1% vermi-humus has a negative impact on the growth performance of broilers, although the immune functions were improved. But the feed supplemented with 3% EWM and 1% vermi-humus can improve the performance of broilers and increase relative weight of immune organs, intestinal length, and intestinal lactic acid bacteria count (Chashmidari *et al*., 2021)

Conclusions

Nutritional research has contributed significantly to poultry production over the years. Its role in the poultry sector is more crucial than ever before in sustaining progress made in the sector as world population continues to increase at alarming rate. The future research should focus more about efficiency of meat/egg production, meat/egg quality and safety for human consumption, feed efficiency to reduce environmental pollution and health and welfare of birds. In future, nutrition objectives will require scientists to use extensive interdisciplinary approaches.

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Chapter 9

GUT HEALTH AND NUTRITION: ROLE OF DIETARY PROBIOTICS FOR NEONATAL HEALTH OF CALVES

Dr. Nutan Chauhan and Dr. Sachin Kumar
Animal Nutrition Division,
ICAR-National Dairy Research Institute,
Karnal-132001, Haryana, INDIA
Email: arensachin@gmail.com

Introduction

Gut health is increasingly becoming an interesting researchable area of animal nutrition while considering animal production. Optimal gastrointestinal tract (GIT) health and its functionality are essential for sustainable animal production (Celi et al., 2017). However, GIT functionality and health are the outcomes of several complex mechanisms. Therefore, it is essential to deepen our knowledge of these interactions for the modulation of gut health in the perspective of improving animal performance. In general, the term 'gut health' refers to a state of a largely symptom-free bowel status and is often associated with 'the absence of clinical diseases' in human medicine (Bischoff, 2011). However, this definition cannot be applied in the case of animal nutrition because of the involvement of the 'production' component; as such, it is well understood that animal performance can be compromised even without apparent clinical signs of any disease.

Optimal gut health is assumed to encompass several physiological and functional features, integrating six principal domains of gastrointestinal functionality, namely diet, intestinal permeability & gut microbiota, effective nutrient digestion and absorption, gut mucosa, barrier function, and effective mucosal immune status (Kogut and Arsenault, 2016). All these components play a pivotal role in gastrointestinal physiology, animal health, welfare, and performance. So, a more comprehensive definition of gut health from an animal nutrition standpoint of view, therefore, would be “a steady-state where the microbiome and the intestinal tract exist in symbiotic equilibrium and where the welfare and performance of the animal are not constrained by intestinal dysfunction” (Celi *et al.,* 2017).

A high standard of animal health and welfare has striven in modern animal husbandry. Early life health and nutrition represent a precondition for a superior constitution and result in high productivity later in life. Besides, the recent changes in feed regulations and animal production management, both regulatory and consumer-driven, have impelled finding new means to optimize gut health in novel and effective ways (Kogut and Arsenault, 2016). Accordingly, many additives have been suggested, and in recent times, probiotics have evolved as novel feed additives to encourage overall wellness and to stabilize gastrointestinal microbiota specifically as an alternative to antibiotics (Kumar et al., 2022a). It is well established that feeding calves with probiotics, especially lactic acid bacteria, improves the health of the gut with a subsequent rise in the effectiveness of digestion and thus enhanced growth performance (Varada *et al.,* 2022a).

The early life and role of gut

The newborn calf's digestive tract is sterile at birth, like all mammalian species, and microflora vertically transmits from contact with the mother and nature, prompting a change necessary for morphological and immunological development of the GIT and neonatal resistance to pathogens. During conception, calves receive their nutrients through the placental transfer from their dam, and after birth, they get all their nutrition from milk (Ballou *et al.,* 2013). According to Dimmitt et al. (2010), the structure of the cells lining the gastrointestinal tract undergoes many changes during the first few weeks of life. Notably, they reported that fetal-type cells are replaced with more adult-like cells within 5-7 days after birth. This epithelial cell lining acts as the first line of defense or the physical barrier of the immune system.

The aggregate of reticulo-rumen, omasum, abomasum, and intestines in ruminants accounts for as much as 71% of the body weight (Meale *et al.,* 2014). From the structural point of view, the gut (lower gastrointestinal tract) includes most of the small intestine and all of the large intestine. Hence, this practically excludes the metabolic and functional aspects of the rumen from the ambit of gut health. The large mass of the GIT compared to the total body mass involves diverse physiological processes that demand abundant nutrients for the maintenance and turnover of tissues. However, when it comes to the role of gut health in determining the host metabolism and immune response the concepts are equally relevant to ruminant livestock as it is for the monogastric farm animals.

Nevertheless, the concepts do have a direct application in the case of newborn calves until the development of a fully functional GI tract. GIT has a clear and evident role in the digestion of feed and the assimilation of nutrients. At the site of nutrient absorption, magnification of the villi and microvilli increases the surface area of the intestine, which maximizes digestion and absorption potential. The gut is considered to be the principal organ of the immune system as it harbors more than 70% of the cells of the immune system (Vighi *et al.,* 2008). The GIT barrier is composed of a mucus layer (threonine-rich glycoprotein), which is a physical or external barrier that impedes direct contact between the enterocyte and the contents of the lumen. Besides, it acts as a barrier to toxins, dietary antigens, and invading pathogens (Chung and Kasper, 2010). Any breach in the integrity of the gut leads to the reduced thickness of the barrier, altered synthesis and function of tight junction proteins, or intestinal hyper-permeability which is more commonly known as "leaky gut", indicating a loss of selective permeability of the intestinal epithelium (Bischoff, 2011). Overall, optimum intestinal barrier function for intestinal integrity is essential for maintaining healthy gut function and, therefore, for the growth and performance of farm animals.

Components of gut health

Conway (1994) proposed three major components of gut health i) Diet ii) mucosa iii) microbiota.

Diet

Diet is one of the significant factors which influence the composition of gut microflora, as the ingested nutrients play a substantial role in the development of GIT and its functionality. Diet composition (ingredients, nutrients, and additives) can modify the development and function of the digestive system, together with the immune system and the microbiota through several distinct mechanisms (Conway, 1994). The ability of feed additives, functional foods, and nutraceuticals in sustaining animal production performance and health has been widely researched (Hoste et al., 2015). Besides, nutraceutical approaches have been documented to benefit the immune system and modulate the redox balance and inflammatory response. Antioxidants are regularly supplemented in the diet of livestock to counteract the adverse effects of increased ROS (reactive oxygen species) production and to improve their health and productivity.

Functional properties of feed ingredients and additives are related to gastrointestinal health and therefore, need to be considered while formulating the diet. Particularly dietary protein appears to be a major nutritional factor in securing immune homeostasis in the GIT. Moreover, diet can influence the GI tract microbiota composition and its metabolic activity, modulating the production of antimicrobial peptides (Yeoman and White, 2014). The effects of diet on GIT health can be directed toward the different functions of the gastrointestinal system. The physical form (e.g. pellet vs crumbles vs mash) and particle size (coarse vs fine), and distribution of the diet exert significant influence on gastrointestinal functionality. For example, calves fed a ground diet had shorter papillae with a lower surface area relative to the calves fed an unground diet. Moreover, the consumption of finely ground diets can decrease the ruminal pH and contribute to rumen parakeratosis (Pazoki *et al.,* 2017).

The mucosa (the innermost layer of the GIT)

The first layer of the gastrointestinal barrier is composed of a mucus layer which is formed by an outer monolayer of intestinal epithelial cells associated with the microbiota and an inner layer with high concentrations of mucin (Bischoff, 2011). The innate immune system of the GIT consists of an underlying set of cells, such as dendritic cells, mesenchymal cells, lymphocytes, and macrophages constituting the gut-associated lymphoid tissue (GALT) (Celi *et al.,* 2017). All of which lead to a strong immune response to invading pathogens, while keeping a fine balance between tolerance to the commensal bacteria and response to pathogens without generating an overt inflammatory response (Kogut and Arsenault, 2016).

The intestinal tract is an active immunological organ with more resident immune cells compared to the rest of the body. It consists of digestive secretions, cell products like cytokines, immune molecules, inflammatory mediators, and microorganisms (Celi *et al.,* 2017). These secretory compounds restrict the growth of microbiota on the mucosal layer. For example, the gut microbiota stimulates mucosal IgA secretion, produces antibacterial substances, and enhances tight junctions of the intestinal barrier, which protect against pathogen invasion in the gut (Roda *et al.,* 2010). Intestinal epithelial cells (IEC) are central to this mechanism as they secrete and govern the mucus layer structure and communicate with the underlying cells.

An effective immune response is deemed to optimize feed efficiency and gut health. Stimulation of the immune system to encounter pathogens may result in compromised growth potential and reduced feed efficiency, resulting in a higher cost of production for farmers. In a broad sense, an effective and functional GIT barrier comprises three components, namely mechanical barrier, immunological barrier, and ecological barrier. Functional entities with various components of barriers coordinate, solely or interactively for the maintenance of a normal permeability to achieve gut health (Bischoff, 2011).

Indigenous Gut microbiota

The gut is home to a complex and dynamic assemblage of hundreds of species containing trillions of microorganisms. These commensal microbiotas colonize the intestine right after birth and are essential for the development and health of the host. The composition is species-specific, which varies during life between organisms and within the same organism (Frese *et al.,* 2012). Many factors can influence the gut microbiota composition, including diet, age, adhesion capacity to the mucus, ingestion of antibiotics, diseases, stress, infection by pathogens, and other management incidents. The microbial community in the gut is an active component of the host's immunity and physiology. The gut microbiota confers an array of health benefits to the host, which includes i) Digestion and absorption of nutrients, ii) Construction of the intestinal epithelial barrier, iii) Development and function of the host immune system, and iv) Competition with pathogenic microbes to prevent their harmful proliferation (Guarner, 2006).

The commensal flora helps the host to ferment indigestible dietary substrates and thus improve the overall intake of nutrients by providing short-chain fatty acids (SCFA), vitamins, and amino acids for the body. Microbial SCFA production accounts for up to 70% of the daily energy supply of herbivores and up to 10% of omnivores (Sanz *et al.,* 2010). Additionally, gut bacteria are an essential source of vitamins B and K for the host (Hill, 1997). These functions highlight the importance of early life microbiota establishment in the GIT and consequently their manipulation as an attractive tool to improve gut health influencing the health and performance of the animals.

Under dysbiosis conditions, there is an unusual change in the microbiota makeup resulting in either a decrease of symbiont numbers and/or a rise in pathobiont count, resulting in the reduced production of anti-inflammatory substances and metabolites (butyrate, organic acids) that are vital for the maintenance of optimum gut health. Therefore, a healthy, stable, and diverse microbiota is required for optimal gastrointestinal functionality. With the adoption of the next-generation sequencing method, we are getting a deeper insight into the understanding of "normal" or "optimal" microbiota composition and its functions. The use of the "omics" approach might unravel the complex intestinal ecology.

The commensal microbiome and the enteric infections in young ruminants

Raising newborn calves is a challenging task in dairy enterprises. 50% of the total death of neonatal dairy calves is caused by enteric infections (Cho and Yoon, 2014). According to recent reports, the gut microbiome establishes within the first seven weeks of life and is associated with growth (neonatal diarrhea, weight gain, and pneumonia) and the health of calves. A possible link exists between gut microbiota and host health. For example, healthy calves had higher bacterial diversity compared to calves with pneumonia and neonatal diarrhea. Proper management of calf rearing plays an essential role in maintaining calf health and thus, reduces economic loss (Varada et al., 2022a). In the modern dairy industry, commonly colostrum is fed immediately after the birth of calves. Feeding calves with highly contaminated (bacteria>106 CFU/ml, coliform>103 CFU/ml) and poor quality (IgG, <50 mg/ml) colostrum (Morrill et al., 2012) can also affect the passive immunity and health (Hang et al., 2017). Therefore, augmentation of gut health during early life is critical for preventing infection and lowering mortality and morbidity of neonatal calves.

Manipulation of the early gut microbiome to improve health and production

In the livestock industry, several feed additives are commonly used as nutritional strategies to improve gut health (by altering rumen fermentation and preventing pathogen colonization) in ruminants (Weimer, 2015). Several bioactive ingredients are available for rumen microbial manipulation: viz. probiotics, prebiotics, ionophores (monensin), essential oils, bioactive proteins, and fats. Probiotics, along with plant or yeast-derived prebiotics are being increasingly used as potential nutraceutical additives and their multiple mechanisms of action invariably revolve around the functioning of gut microbiota, both directly and indirectly. However, most of these outcomes are effective only in pre-weaned calves and last only till the treatment period, suggesting that dietary manipulations are either temporary or should be implemented within a given period of development so that they can trigger persistent changes in the microbiome. Besides, it is essential to know how these gut microbial communities react to dietary manipulations and how their compositional changes affect the overall metabolic and immune functions of the gut.

Probiotics and gut health in neonatal calf

Probiotics are “the live microorganisms which when administered in adequate amount confer health benefits on animals”. In neonatal calves, rapid changes in diet, environment and other stresses imbalance gut and allow colonization of opportunistic pathogens particularly leading to diarrhoea. Antibiotics are given therapeutically to solve these problems but, the negative effects of antibiotics are increasing seriously (Singh *et al.,* 2021). In this context, probiotics can be a promising approach in promoting animal health and stabilization of gut microbiota (Varada *et al.,* 2022a; Ojha *et al.,* 2022). The activity of probiotics depends on their genera, species or strain and can be applied as monospecies or multispecies in livestock feed (Timmerman *et al.,* 2004). Dose, timing and duration of the administration of probiotics determine their efficacy. For example, higher dose of probiotic given for short period of time seems to be more effective than lower doses in acute infectious diarrhoea in calves (Sazawal *et al.,* 2006). Selection of potential and effective probiotics for new-born calves is crucial. Autochthonous probiotics which are normally residing in the hosts digestive tract are more effective than allochthonous species (Frese *et al.,* 2012). It has been well established that feeding probiotics to suckling calves has shown to improve digestion. Lactic acid bacteria (LAB) and bifidobacteria most widely used as probiotics belong to the group. However, Lactobacillus seems to be the most potential probiotic in monogastric animals' gut that prevents the colonization of pathogenic bacteria by establishing a protective biofilm. On the other hand, host-species specificity is recognized as a criterion for showing the probiotic's beneficial properties (Singh *et al.,* 2021). Besides, probiotics' adhesion and beneficial effects are often higher when they are obtained from the same animal species. Therefore, selection and evaluation of novel probiotics, especially from relatively unexplored ecosystems, has been a continuous practice with beneficial actions on gut health (Varada *et al.,* 2022b; Chouraddi *et al.,* 2023).

Sharma *et al.* (2018) studied the effect of mannan-oligosaccharides (MOS) and Lactobacillus acidophilus supplementation on growth performance, nutrient utilization and faecal characteristics in Murrah buffalo calves. He concluded that the incorporation of MOS and Lactobacillus acidophilus in diet either individually or in combination as synbiotic has the potential to improve the performance and faecal characteristics in Murrah buffalo calves; however, the observed responses among the treatment groups were more evident in the synbiotic fed group compared to individual supplementation of MOS and Lactobacillus acidophilus.

Singh *et al.* (2021) had isolated Lactobacillus strains from the faecal samples of Murrah buffalo calves and attempts have been made to investigate their probiotic potential in vitro. A total of 96 isolates based on Gram-positive, catalase negative and resistant to vancomycin; 55 isolates have been presumptively identified as Lactobacillus species and further confirmed by genus specific PCR. Based on cell surface hydrophobicity and auto-aggregation, 17 isolates were selected and further grouped by amplified ribosomal DNA restriction analysis (ARDRA) and identified by 16S rDNA sequencing. The principal component analysis and biplot projection based on probiotic attributes indicated L. reuteri BF-E7 and L. salivarius BF-17 were found to be most promising probiotic candidates for future applications.

Varada *et al.* (2022b) was evaluated the effect of autochthonous probiotics on Murrah buffalo calves. Sixteen calves (5-7days of age) were randomly divided into four groups. Group I served as control (CT), fed a basal diet with no supplementation. Groups II (LR), III (LS), and IV (CS) were supplemented with Limosilactobacillus reuteri BF-E7, Ligilactobacillus salivarius BF-17, and a consortium of both probiotic strains at a rate of 1x108 CFU/g/calf per day along with the basal diet, respectively. Both potential probiotic strains, Limosilactobacillus reuteri BF-E7 and Ligilactobacillus salivarius BF-17, were found to be compatible in vitro. Dietary supplementation of probiotics for sixty days significantly increased ($P<0.05$) dry matter intake (DMI, g/d), average daily gain (ADG, g/d), net body weight gain (kg), feed conversion efficiency (FCE), and structural growth measurements as compared to control. Furthermore, a considerable ($P<0.05$) increase in the abundance of beneficial intestinal microbiota (lactobacilli and bifidobacteria) was observed along with improvement in fecal biomarkers like lactate and ammonia, immune status, and reduced fecal score.

Chouraddi *et al.* (2023) had isolated, 105 bacterial colonies from the feces of newborn healthy Bos indicus calves and 37 isolates were confirmed using morphological, biochemical tests, and genus-specific PCR as lactobacilli. 11 isolates were then short-listed for in vitro probiotic testing based on their ability to dwell under acid and bile stress. Species-level identification using 16rRNA gene sequencing revealed that they were Ligilactobacillus salivarius. These isolates produced digestive enzymes like amylase, protease, and β-galactosidase and have antimicrobial & coaggregation potential against diarrhea-causing pathogens like Escherichia coli ATCC-25922 and Salmonella arizonae ATCC-13314. L. salivarius was revealed to be the most effective potentail probiotic option for upcoming uses.

Varada *et al.* (2022c) had studied the effect of host-specific probiotics on gut health and animal performance in preruminant buffalo calves. Eight Murrah buffalo calves (3–5 days old; 32.52 ± 0.43 kg average body weight (BW)) were randomly allocated into two groups as follows; 1) Group I (n = 4) fed basal diet alone (CON); 2) Group II (n = 4) supplemented with a lyophilized probiotic formulation at a dose rate of 1 g/day/head (1 × 109 CFU/g) having Limosilactobacillus reuteri BF-E7 and Ligilactobacillus salivarius BF-17 along with basal diet (PF) for 30 days. Results revealed that final BW (kg), average daily gain (g/day), average dry matter intake (g/day), and structural growth measurements were significantly ($P < 0.05$) increased in the probiotics supplemented group (PF) compared to the control (CON). Fecal pH, fecal moisture, and fecal score were reduced ($P < 0.05$) in PF than in CON. Moreover, levels of fecal propionate, lactate, and ammonia altered positively in PF compared with CON. The relative abundance of Firmicutes tended to be higher ($P = 0.10$) in the probiotics fed group than CON. However, the relative abundance of Proteobacteria was significantly lower ($P = 0.03$) for calves fed probiotics on day 15. A trend was observed in Bacteroides ($P = 0.07$) and Lactobacillus ($P = 0.08$) abundances in the feces of the PF than in CON. Overall, it can be concluded that the administration of probiotic formulations significantly improved the performance and gut health of buffalo calves via modulating the gut microbiota composition.

To develop novel host-specific probiotic for their application as feed additive, Kumar *et al.* (2022b) isolated and characterize probiotic strains of indigenous cattle-calves origin. A total of 55 colonies were isolated from 12 healthy calves, with 34 of the isolates being Gram-positive, catalase-negative and vancomycin-resistant. Furthermore, eleven isolates showed tolerance to acid (pH 2.0) and thirteen isolates tolerated bile salts (0.3%). Seven common acid and bile tolerance strains were further investigated for other probiotic attributes and displayed higher ($p< 0.05$) auto-aggregation and cell surface hydrophobicity values. Moreover, all seven isolates had potent antibacterial activity against pathobiont E. coli as well as significant co-aggregation capacity and enzyme activity. Based on the obtained findings, heatmap and principal component analysis identified four highly effective probiotic candidates confirmed by 16S rDNA sequencing as Limosilactobacillus reuteri SW23, Limosilactobacillus reuteri SW26, Limosilactobacillus reuteri SW27 and Enterococcus faecium SW28, respectively. Further studies on biosafety aspect are warranted for the application of these strains in animal as potential probiotics.

Conclusions

A healthy gut microbiota is a key determinant factor for maintaining the health of neonatal calves which prevents the potential gut microbial-associated diseases. Optimizing gastrointestinal health and its function is recognized as an effective strategic approach for sustainable animal production. Autochthonous probiotics were found more effective in modulating the gut health of neonatal calves compared to allochthonous probiotics. However, it would be more logical to focus future research strategies impacting early life nutrition and calf's gut health for animals' lifetime performance.

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Chapter 10
HERBAL FEED ADDITIVES IN ANIMAL HEALTH AND MANAGEMENT

Dr. Roopa Krishna Reddy. PhD (Animal Nutrition),
International Business Development Manager, Europe continent,
Natural Remedies Private Limited- Bangalore – 560100
Email:roopa.k@naturalremedy.com

Introduction

World Organization for Animal Health (OIE), the leading international body has defined animal well-being as a complete physical and mental health of an animal and the ability to adapt to the surrounding environment (Lopez, 2007). It covers good animal husbandry, animal care, management, and veterinary treatment. The stakeholders like animal health product companies, livestock industries, non-governmental organizations, veterinarians, animal transporters and food marketing institutions need to work together to eliminate the suffering of the animals. The major threats posed to animal health in recent decades are emerging diseases like African swine fever, avian influenza or lumpy skin disease which may spread from one country to another. Due to the failure of developing appropriate preventive measures against these sudden arising diseases, animal health remains at risk. Thus, animal health care companies need to provide strong vigilance on disease transmission and suitable remedies. There should be corporate-friendly policies and companies should spend more in the R&D sector to innovate new products. Furthermore, as the animal farming system is maintained at a higher density, the chances of the rapid spread of disease among the colony exceed. Thus a proper quarantine method is essential to immediately isolate the sick animals from the herd to avoid the contagious propagation of illness. Moreover, Animals are often exposed to the stressors like changes in food habits, variations in environmental temperature and humidity, confined and high-density animal husbandry practice, social stress like isolation, weaning, disease conditions, and influence on high production rate, caging of layer birds without proper exercise etc. These external stress factors cause impaired immune response as well as a disturbance in the body’s homeostasis leading to a negative impact on the growth, reproduction and overall performance of the animals.

Antibiotics are being used for a long period of time as a growth promoter (AGP) in the animal ration. They have a promising impact on the disease prevention and performance of the animals. However, the United States Food and Drug Administration (USFDA) has banned the use of antibiotics in the ration of food-producing animals (FDA 2013). Many food-producing animals require a high dose of antibiotics due to their large size. The residue of antibiotics may enter the human food chain if the animals are slaughtered before the specific withdrawal period. and cause health hazards to consumers due to antibiotic resistance. To combat these challenges, the companies need to set the motto "prevention is better than cure" and put forward a holistic approach. New technologies may be developed to improve animal nutrition rather than using antibiotics on farms. Many synthetic feed supplements like zinc oxide (ZnO), choline chloride etc are frequently used in the ration of animals and birds to promote their health and efficiency. Zinc is a trace element that plays a crucial role in animal nutrition. In addition, choline is an essential component to mobilize the excess accumulated fat in the liver and prevent fatty liver disease. However, extensive use of these products in animal diet may cause alteration of gut microbiota and pose threat to the environment leading to health hazards (Selvam *et al*., 2018). Scientists have introduced probiotics as feed additives in animal diets. Probiotics are direct-fed microbials that are nontoxic and improve the digestive health of animals. Unlike antibiotics, probiotics do not cause any harm to the consumers of the food-producing animals due to their presence as residue. Inclusion of probiotics in animal ration help in gut tissue maturation and modulation of immune response and gut microbiota resulting in an improvement of the overall performance (Grant, Gay, and Lillehoj 2018). But tremendous use of probiotics develops safety issues and causes harm to the environment (Reuter 2001). **Therefore, investigators are searching for an alternative feed additive of plant origin to promote the growth and performance of the animals**. Myriads of literature stated that plants have an important role in nutrient digestion, metabolism, energy distribution and prevention the toxin secretion. Phytogenic feed additives (PFA) are plant-derived bioactive compounds that have a potential impact on promoting animal health. Various active phytochemicals including flavonoids, terpenoids, polyphenols, carotenoids, coumarins, saponins and plant sterols are widely available in plants (Murugesan *et al.,* 2015). They elucidate their role as an antioxidant, anti-inflammatory, anti-microbial and immunomodulator. They may effectively reduce oxidative stress by upregulating the antioxidant enzymes that have an important role in neutralizing the harmful reactive oxygen species (ROS) level and detoxification of xenobiotics. Thus, the plant-derived bioactive compounds are promising hepato-protectants (Mohamed Saleem *et al.,* 2010). As the liver is the prime organ for the nutrient metabolism and purification of harmful substances, the liver health of animals needs to be emphasized. Supplementation of these photogenic compounds to the animal feed and drinking water helps to enhance the feed intake, feed conversion ratio, and production efficiency. They actively improve the defense mechanism through cell-mediated as well as antibody-mediated immunity of the body resulting in the enhancement of overall immune response. PFA attributes to controlling harmful pathogens present in the intestine and favorably modulates gut microbiota resulting in enhanced nutrient digestibility. Therefore, PFA effectively upregulates the overall health status and the productive performance of the animals.

Emblica officinalis	Hydrolysable tannins, anthocyanin, flavonoids, phenolic acids
Withania somnifera	Steroidal alkaloids saponins, glycosides and volatile oils
Ocimum tenuiflorum	Eugenol rosmarinic acid apigenin,
Andrographis paniculate	Flavonoids, alkaloids, tannins, triterpenoids, and polyphenols

Figure 1: Common plants and their bioactive compounds used in animal

Shatavari (Asparagus racemosus) is an ethnopharmacological acclaimed ayurvedic medicinal plant of Asparagaceae family and is called as ‘Queen of Herbs’ in Ayurveda. Shatavari, well known for its adaptogenic, galactogogue, anabolic, diuretic, rejuvenating, carminative, stomachic, antiseptic, emollient, cooling, nervine tonic activity antimicrobial, antioxidant, antiulcer, phytoestrogenic effects, neuroprotective effect, etc. As a growth promoter and immuno-stimulant, it can enhance nutrient utilization efficiency and performance of livestock and poultry. A holistic approach to making use of Shatavari as a feed additive in livestock and poultry production could help in amelioration of excessive stress on the production capacity of livestock and poultry (Bharati and Satish, 2019). Indian gooseberry or amla (Phyllanthus Emblica Linn or Emblica officinalis Gaertn.) is a valuably most important medicinal plant in Indian traditional system of medicine, i.e. in Ayurveda. Various parts of the plant are used to treat a range of diseases or used as feed additives in animals, but the most important part is fruit. The fruit is rich in quercetin, phyllanthocin compounds, gallic acid, tannins, flavonoids, pectin and vitamin C and also contains various polyphenolic compounds. A wide range of phytochemical components including terpenoids, alkaloids, flavonoids and tannins have been shown to possess useful biological activities. Wide range of action such as antipyretic, analgesic, antitussive, antiatherogenic, adaptogenic, cardioprotective, gastroprotective, antianemia, anti-hypercholesterolemia, wound healing, antidiarrheal, ant atherosclerotic, hepatoprotective, nephroprotective and neuroprotective properties. Amla is also reported to possess radio modulator, chemo modulatory, chemo-preventive effects, free radical scavenging, antioxidant, anti-inflammatory, antimutagenic and immunomodulatory activities (Sunil. *et al.,* 2018). The study was done to assess the efficacy of phytogenic feed additives as an alternative to antibiotic on growth performance of broiler chicken and it revealed that amla supplementation at the rate of 0.75% can improve FCR, weight gain and Dry Matter metabolizability and Nitrogen metabolizability (Dalal *et al.,* 2018). Ashwagandha (Withania somnifera) is a well-known herb possessing several health benefits. Steroidal alkaloids and lactones are the main active constituents of the plant. It consists of following properties viz. adaptogenic, antidepressant, liver-tonic, antioxidant, immune modulator, immune adjuvant, anticarcinogenic, anti-metastatic. Supplementation of Ashwagandha in diet of poultry birds improves feed intake, body weight gain, feed conversion ratio, haematological profile, immunological status, neuroprotective, rejuvenate muscles, lipid profile, gut microflora and intestinal morphometry. The effect of birds fed ration supplemented with Ashwagandha at different levels gradually improved feed intake, body weight, feed efficiency and nutrient metabolizability (Jyotsana *et al.,* 2019). Studies recommends the addition of 1% Ashwagandha in the basal diet of broiler production to get more profit in commercial broiler farming (Saini *et al.,* 2022).

Ayurveda's use of medicinal and culinary herbs draws upon India's incredible biodiversity with a variety that is unsurpassed by any medical system; yet, of all the herbs used, none has a status comparable to tulsi or holy basil (Ocimum sanctum). Holy basil has shown many beneficial effects like adaptogenic, antibacterial, antioxidant, anti-inflammatory, analgesic etc. Biswas et al 2020 have done research and concluded that NTG (Leaves of Neem and Tulsi, and gingers) extract is an effective and alternative of antibiotic growth promoters. Andrographis paniculata (Burm. f.) Neem is an annual herb widely distributed in tropical Asian countries and is native to India and Sri Lanka. The leaves and roots of the plant are used to treat several diseases, such as cancer, diabetes, high blood pressure, ulcer, leprosy, bronchitis, skin diseases, flatulence, colic, influenza, dysentery, dyspepsia, and malaria. Andrographolide is the major constituent extracted from the leaves. Crude extracts and bioactive constituents of the plant have been reported for their antimicrobial, cytotoxicity, anti-protozoan, anti-inflammatory, antioxidant, immunostimulant, antidiabetic, anti-infective, anti-angiogenic, hepato-renal protective, sex hormone/sexual function modulation, liver enzymes modulation, insecticidal, and toxicity activities (Mundada. *et al.,* 2022).

Conclusion

Phytogenic compounds are efficacious in promoting the health status of animals and are a good substitution for AGP. Thus herbal feed supplements are effective to overcome the challenges of animal welfare.

Figure 2: Livestock and birds susceptible to various challenges

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E - BOOK

EMERGING TRENDS IN LIVESTOCK NUTRITION FOR HEALTH AND PRODUCTION

Dr. Chethan K.P., Dr. Hemanth Gowda K., Dr. Shahaji Phand, Dr. Sushrirekha Das

This e-book is a compilation of resource text obtained from various subject experts for the Collaborative Online Training Programme of Karnataka Veterinary Animal and Fisheries Sciences University (B), Karnataka & MANAGE, Hyderabad, Telangana on "Emerging trends in Livestock Nutrition for Health and Production" conducted from 29th – 31st May, 2023. This e-book is designed to educate extension workers, students, research scholars, and academicians related to veterinary science and animal husbandry about various technologies in Livestock Nutrition for improvement of Health and Production.

EDITORS




Dr. Chethan, K. P.
Associate Professor (i/c)
Veterinary College, KVAFSU
Hassan

Dr. Hemanth Gowda K.
Assistant Professor
Veterinary College, KVAFSU
Hassan

Dr. Shahaji Phand
Deputy Director
(EAAS), MANAGE, Hyderabad

Dr. Sushrirekha Das.
MANAGE Fellow,
EAAS, MANAGE, Hyderabad

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