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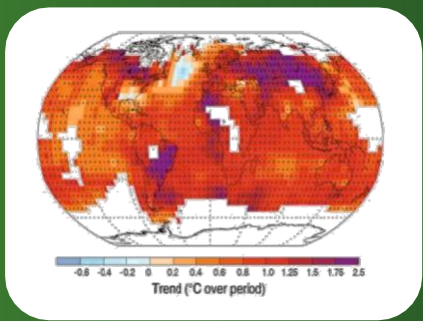
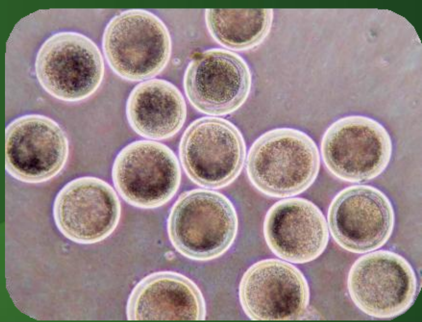
Nutrition and Fertility Management of Dairy Animals in Changing Climate Scenario



Edited by
Shahaji Phand, N K S Gowda, S Selvaraju,
K Giridhar, B Krishnappa and Raghavendra Bhatta

ICAR-National Institute of Animal Nutrition and Physiology (ICAR-NIANP), Bengaluru
&
National Institute of Agricultural Extension Management, Hyderabad

ICAR-NIANP, Bengaluru
&
MANAGE, Hyderabad

Nutrition and Fertility Management of Dairy Animals in Changing Climate Scenario

Programme Coordination

ICAR-National Institute of Animal Nutrition and Physiology, Bengaluru

Jointly Published By

ICAR-NIANP, Bengaluru

&

MANAGE, Hyderabad

Nutrition and Fertility Management of Dairy Animals in Changing Climate Scenario

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Published for Dr.P.Chandra Shekara, Director General, National Institute of Agricultural Extension Management (MANAGE), Hyderabad, India by Dr.Srinivasacharyulu Attaluri, Program Officer, MANAGE and printed at MANAGE, Hyderabad as e-publication.

Message

National Institute of Agricultural Extension Management (MANAGE), Hyderabad is an autonomous organization under the Ministry of Agriculture & Farmers Welfare, Government of India. The policies of liberalization and globalization of the economy and the level of agricultural technology becoming more sophisticated and complex, calls for major initiatives towards reorientation and modernization of the agricultural extension system. Effective ways of managing the extension system needed to be evolved and extension organizations enabled to transform the existing set up through professional guidance and training of critical manpower. MANAGE is the response to this imperative need. 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.

Dairy is essential in the endeavour towards ending hunger, achieving food security and improving the nutritional value of diets in a sustainable manner and nutrition is the most important factor affecting the animal production and performance in the changing climate scenario. The major reasons for nutritional stress are environmental stress (especially heat stress, where animals voluntarily reduce feed intake) and pasture scarcity. Under the changing climate scenario livestock production is affected by low pasture availability during the summer, and changes in temperature, precipitation and increased CO2 levels have resulted in declining grain quality of crops. Reduced nutritive value of fodder crops is one of the primary indirect effects of climate change on livestock production. Hence various alternative strategies are to be adopted to maintain productivity especially during the deficit period or summer when the availability of pasture and water declines. Thus in order to sustain the productivity, suitable nutritional interventions are to be adopted like management of forage for the dry period, utilization of the non-conventional feed resources as alternatives, antioxidant supplementations during the stress period, and also water management strategies for both surface and ground water resources, at both local and national levels, as fresh and contamination free water is crucial for animal production. These efforts will ensure economically viable returns in livestock farms in the changing climate scenario.

It is a pleasure to note that, ICAR-National Institute of Animal Nutrition and Physiology (ICAR-NIANP), Bengaluru and MANAGE, Hyderabad, Telangana is organizing a collaborative training program on “Nutrition and Fertility Management of Dairy Animals in Changing Climate Scenario” from 21-23 December, 2021 and coming up with a joint publication as e-book on “Nutrition and Fertility Management of Dairy Animals in Changing Climate Scenario” as immediate outcome of the training program.

I wish the program be very purposeful and meaningful to the participants and also the e-book will be useful for stakeholders across the country. I extend my best wishes for success of the program and also I wish ICAR - National Institute of Animal Nutrition and Physiology (ICAR-NIANP), Bengaluru, many more glorious years in service of Indian agriculture and allied sector ultimately benefitting the farmers. I would like to compliment the eGorts of Dr. Shahaji Phand, Center Head-EAAS, MANAGE, Hyderabad, Dr. Raghavendra Bhatta, Director, ICAR-NIANP, Bengaluru and the Dr. N K S Gowda, Principal Scientist & Incharge, ATIC, ICAR-NIANP, Bengaluru, for this valuable publication.

Dr. P. Chandra Shekara
Director General, MANAGE

Foreword

India is the largest milk producer in the world and dairying has moved from secondary to primary occupation supporting millions of livelihoods. This has been possible due to the relentless efforts of breeders, veterinarians, nutritionists, health specialists, policy makers and dairy processing network. The changing lifestyle and increase in purchasing power of consumers are likely to enhance the demand for animal products like milk. The projected demand of milk in India by 2025 is about 230 million tonnes. Reducing the cost of feeding, improving fertility and better health care are going to be the major challenges to achieve this targeted milk production. Balanced feeding and good nutrition play a key role in optimising milk production both quantitatively and qualitatively. The potential of both crossbred and indigenous dairy animals can be exploited only by scientific feeding and management. Change in the climate and environmental factors put additional stress on livestock production. Low reproductive efficiency is another problem in Indian dairy livestock and requires continuous effort to address this issue. Higher milk productivity is often related with compromised reproductive efficiency. Majority of the low fertility incidences in dairy animals in India are due to nutritional deficiencies and imbalances, besides endocrinal and infectious causes. The ICAR- NIANP has been mandated to address some of these issues through nutritional and physiological approaches and the Institute has already made commendable progress which has been recognized nationally and internationally. To develop quality human resource across the country, the Institute has been regularly conducting training programmes, workshops and seminars to our stake holders. I sincerely believe that this compendium containing technical articles related to 'Nutrition and Fertility Management of Dairy Animals in Changing Climate Scenario' will be highly useful for the Officers of State Department of Animal Husbandry & Veterinary Services, State Milk Federations and Krishi Vigyana Kendras. I wish fruitful presentation and discussion during the course and wish the programme a grand success.

Raghavendra Bhatta

Director, ICAR-NIANP

PREFACE

Livestock is an essential part of agricultural system all over the world. Livestock production made more effective based upon many factors like environmental stresses, climatic factors, health status, nutrient availability, and genetic potential. In the changing climate scenario, nutritional stress act as the most important indirect stress affecting livestock leading to decreased performance, lower efficiency, increased mortality and it also affects the immune system. The animals in tropics faces the problem of low feed availability during summer and this leads to severe nutritional stress to livestock grazing in the low pasture lands. Under nutrition reduces the quality and quantity of milk production, effects growth potential and reduces body condition score (BCS), induces seasonal weight loss (SWL) The topics have been carefully selected to offer possible solutions to common problems/ issues encountered in a dairy farm. This book was made possible by the sincere efforts of the contributing authors.

This e-book is an outcome of collaborative online training program on "Nutrition and Fertility Management of Dairy Animals in Changing Climate Scenario" conducted from 21-23 December, 2021. This book will be highly useful to field functionaries as well as extension workers who are working at the ground level. A myriad of topics from nutrition to reproduction and management of major diseases has been covered for the benefit of the readers.

The editors express sincere thanks to Raghavendra Bhatta, Director, ICAR-NIANP, for encouragement in publishing this e-book. The financial aid provided by MANAGE, Hyderabad for this training program is duly acknowledged. We hope and believe that the suggestions made in this e-book will help to improve the ability of all the stakeholders to improve nutrition and fertility management of dairy animals in changing climate scenario.

December, 2021

Dr. Shahaji Phand
Dr. N K S Gowda
Dr. S Selvaraju
Dr. K Giridhar
Dr. B Krishnappa
Dr. Raghavendra Bhatta

Contents

LIVESTOCK PRODUCTION AND CLIMATE CHANGE: AN OVERVIEW

Raghavendra Bhatta, P. K. Malik, Atul P Kolte and V. Sejian
ICAR-National Institute of Animal Nutrition and Physiology, Bangalore
ragha0209@yahoo.com

Introduction

The distribution of livestock is not uniform throughout the world and there are inter-regional differences in the distribution, attributed to the agro-ecological features, human population density and cultural norms. The livestock are an integral component of agriculture and contribute directly or indirectly to the populace in various ways. There are 1526 million cattle and buffaloes: 1777 million small ruminants in the world (FAO, 2011). These animals are scattered under grazing (30%), rainfed mixed (38.5%), irrigated mixed (30.15) and landless/industrial (1.15%) production systems. Sub-Saharan Africa, Latin America and the near East have larger land area per person engaged in agriculture and therefore, have a greater livestock proportion dependent on the grasslands. Livestock virtually supports the livelihood of about 1 billion poor across the globe, of which 61% inhabit in South and Southeast Asia (34% in South Asia and 27% in Southeast Asia). Livestock provide over half of the value of global agricultural output and 1/3rd of the developing countries. The share raises with income and living status as evidenced from OECD countries, where livestock contributes above 50% of agricultural GDP. In 2010, the export value of livestock product in international trading was about 180 billion US$ that constitute around 17% of the total agricultural products export value. Approximately, 13% of the total calorie consumption comes from the livestock products, while in developed countries this is ~21% of the total calorie consumption. Additionally, livestock products cater 28% of total protein need, whereas in developed countries it is 48% to the total. Due to the comparatively high cost of livestock products and low income, the consumption of livestock products in developing world is still low. However, in past few years due to the rising income and better living status, a clear transition towards animal products-based diet may be evidently noticed in developing countries.

Livestock and climate change

Livestock systems have both positive and negative impacts on the natural resource base, public health, social equity and economic growth (World Bank, 2009). Livestock are considered a threat for the degradation of rangelands, de-forestation and biodiversity in different eco-regions, and also supplies nitrogen and phosphorus in water. As per one estimate livestock are accountable for 20% rangelands degradation and posing a threat to the biodiversity in 306 of the 825 worldwide eco-regions (Le Gall, 2013). Animal production systems and climate change are intermixed through complex mechanisms and the threat of climate change is ubiquitous to the agriculture and livestock sector, however, the intensity of impact is stratified depending on the agro-climatic region. In one-way, climatic variations influence the livestock production by altering the surrounding environment that governs the well-being and prolificacy of livestock; affecting the crop biomass quality and quantity, animal health etc. On the contrary, livestock production also has large impact on climate change through the emission of large quantity of greenhouse gases (GHGs) associated with livestock rearing and excreta. Climate change have both direct and indirect impacts on livestock; increase in events such drought, floods and cyclones, epidemic diseases, productivity losses and physiological stress are few of the direct impacts of climate change on livestock, while indirect impacts would be on feed and fodders quality and quantity, availability of drinking water, the interactions between the host animal and the pathogen. An overview of livestock production and climate change inter-linking is depicted in figure 1

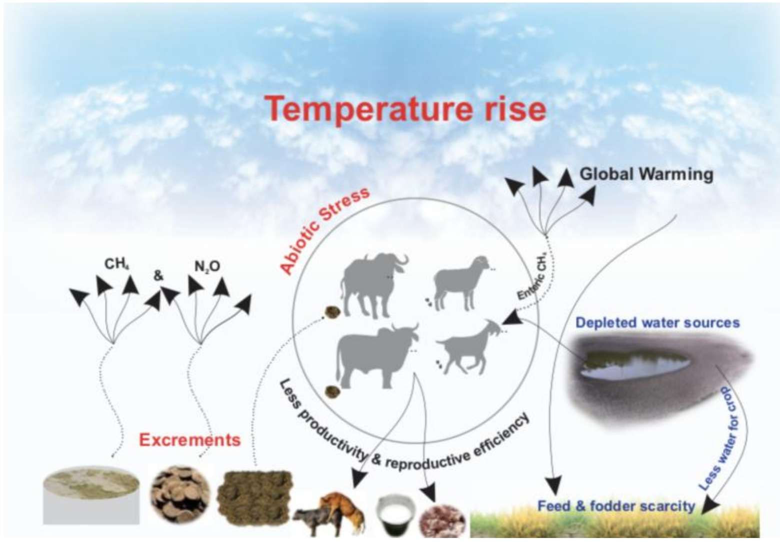

Fig. 1: Inter-linking of livestock production and climate change

Climatic variations influence the livestock production via alterations in ambience (stress), compositional and quantitative changes in fodder crops, health etc. The likely adverse impact of climate change on livestock is summarized in Table 1.0

Table 1.0: Likely impact of climate change on livestock production

Events that may affect with climate change	**Impact**
Droughts with fodder shortages	⇧
Water scarcity	⇧
Heat stress	⇧
Pastoral farming	⇩
Milk production	⇩
Meat production	⇩
Fertility	⇩
Average winter weight loss through thermoregulation	⇩
Incidences of pest & disease	⇧
Herbage biodiversity	⇩

Livestock and greenhouse gas emission

CO_2 is major greenhouse gas (GHG) accountable for more than half of the greenhouse effect; however, the emission from animal as such is negligible and mainly emit from the industries and fuels burning. However, CH_4 is succeeded to CO_2 but its concentration in atmosphere is around 2 ppmv, far less than 396.81ppmv of CO_2. From animal-agriculture, CH_4 and N_2O are the two major GHGs that contribute to the global warming. Livestock rearing have two components for GHGs emissions; one is enteric fermentation, and another is excreta. Enteric fermentation contributes almost 90% of the total CH_4 emission from ruminants as such, and rest comes from the hindgut fermentation. Intensity of CH_4 emission from excreta depends on management system followed; the collection and storage of dung in pit or lagoons create the desirable anaerobic conditions and, therefore, lead more CH_4 emissions from excreta; however, the emission of CH_4 from heap system in most of the developing countries including India is very less as most of the heap portion is exposed to the environment and emission only take place from the inner deep layer. On the contrary, the N_2O emission from the heap system is comparatively more due to the exposure in open environment.

Both CH_4 and N_2O have 25 and 310 times more global warming potential, respectively as compared to CO_2 and therefore, much more important as far as global warming is concern. In the total CH_4 emission of 535Tgper year, 90Tg derives from the enteric fermentation, whereas 25Tg comes from the animal wastes. Animal production systems emit 7.1 Gt CO_2-eqGHGs per annum that represent around 14.5% of the human induced GHG. In addition, the ruminant supply chains are also emit 5.7 Gt CO_2-eqper year, of which 81, 11 and 8% are associated with cattle, buffalo and small ruminant production, respectively. In one estimate, FAO projected that the GHGs emissions from the anticipated livestock numbers may be doubled in the next 35-40 years. This shall precipitate much embroilment as industrial GHGs emission is anticipated to be on decline.

Further, animal production systems are also the largest contributors of reactive nitrogen to the environment in the form of NH_4^+, NH_3, NO_3, N_2O, and NO. However, most these nitrogen losses except N_2O from agriculture does not directly affect climate change, but these compounds have serious environmental consequences by contributing to haze, acidity of rain, eutrophication of surface water bodies, and damage to forests. Intensification of livestock production to satisfy the requirementhas led to rigorous use of manures and fertilizers resulted into saturation and accumulation of phosphorus in soil that creates the problem of eutrophication and impair the ecosystems etc.

Despite removal of unwanted fatal products (H_2& CO_2), ruminal methanogenesis deprives host animals from a sizable fraction of energy (6-12% of the intake) as it consists high calorific value (55.65 MJ/kg). Worldwide the researchers have come up with several methane mitigation strategies to ameliorate the emission up to a meaningful extent. Unfortunately, the country and region-specific precise estimates for enteric CH_4 emission is not known especially for the developing countries and therefore, attempting reduction using specific mitigation approaches will not end up with anything. For example, there is a huge disparity between the enteric CH_4 emission estimates from the Indian livestock and ranged from 7 to 18 million tons per year. One of the major causes for such inaccurate estimate for enteric methane emission is the lack of suitable and validated methodologies for emission measurement and usually workout the emission using different equations which are developed in other countries and there is no similarity at all in the feeding resources, dietary regimes, productivity level etc. The first attempt in targeting the amelioration should be the accurate measurement of emission to decide the extent of reduction and thereafter choosing of approach, which could achieve the desirable reduction. The measurement is necessary 1) to explore the trend and identify that how much is contributing by various livestock species 2) devising of effective ways to mitigate the emission and 3) confirmation of the effectiveness of strategies which is used for intended purpose of reduction (PGgRC, 2015)

Recently, ICAR-NIANP (2017) has developed state wise enteric methane emission inventory (Fig. 2). Our estimate suggested an emission of 9.252 Tg methane per year from the livestock, much lower than estimate by many other agencies. Uttar Pradesh with an emission of 1.52 Tg stands on the top as far as enteric methane emission from Indian livestock is concern.

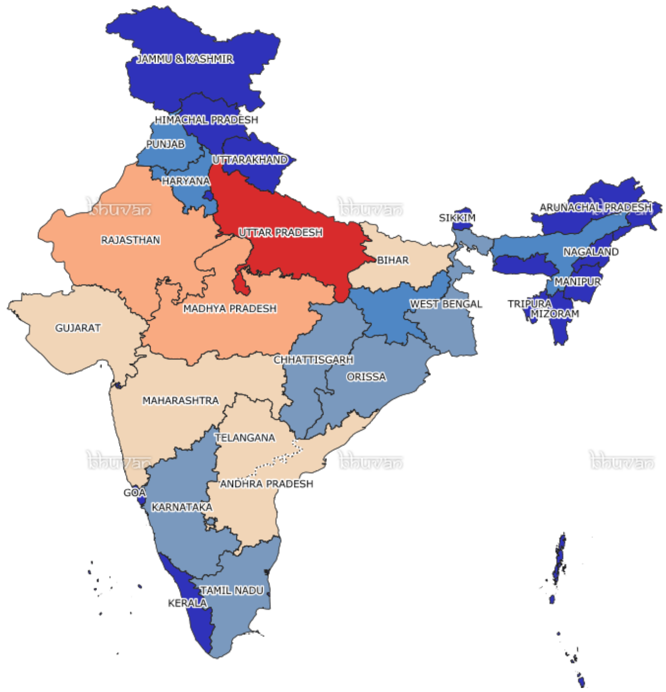

Fig.2: State wise enteric methane emission from Indian livestock (NIANP, 2017)

Impact of stress on livestock

Thermal changes impair the production traitssuch as growth, meat and milk yield and quality, egg yield, weight, and quality and reproductive performance of the animal. Reduction in milk production is one of the major economic impacts of climatic stress in dairy cattle. This impact on milk production is very severe on exotic breeds rather than on indigenous. Decreased synthesis of hepatic glucose and lower non-esterified fatty acid (NEFA) level in blood during heat stress causes reduced glucose supply to the mammary glands resulting in low lactose synthesis, which in turn follows low milk yield. Reduction in milk yield is further intensified by decrease in feed consumption by the animals to compensate high environmental temperature. Around 35% of overall milk reductions due to heat stress are attributed to reduce feed intake and rest 65% reduction are primarily due to direct effect of heat stress on the animals. It is an established fact that reproduction processes are influenced during thermal exposure (Kornmatitsuk et al., 2008). Thermal stress influence on estrous incidences is also awell-established fact. Naqvi et al. (2004) demonstrated that thermal stress significantly altered the super ovulatory response and embryo production in Bharat Merino ewes.

A temperature and humidity level beyond certain level stress the livestock species and temperature higher than 25^{0}C with relative humidity more than 50% has a negative impact on animal functions and productivity. Livestock species have different tolerance level for temperature and humidity that varies in different breeds. Temperature Humidity Index (THI) has been related to animal production functions and animal stress for Indian livestock performance (Upadhyay et al., 2010). Both cattle and buffalo are comfortable at THI between 65 and 72, under mild stress from 72 to 78 and under severe stress above 80.

The THI maps based on average temperature and humidity levels in different months for India indicate that at majority of places THI remain more than 75. More than 85% places in India experience moderate to high heat stress during April, May, and June and THI range 75-85 at 2.00 PM. During May and June at around 25% places THI exceed 85 i.e. severe stress levels. Night temperatures remain high and animals are unable to relieve from heat stress. On an average THI exceed 75 at 75-80% places throughout the year. A progressive increase in THI is depicted in fig. 3.

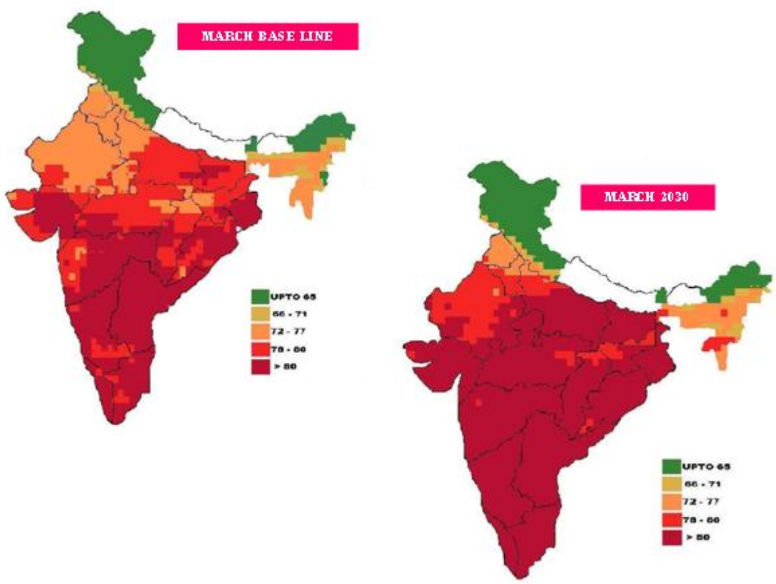

Fig. 3: progressive increase in THI till 2030 (Upadhyay, 2015)

Nutrition plays an important role in the production performance of farm animals. Superior genetic potentiality of livestock is often veiled due to inadequate nutrition resulting in lower growth rate, milk yield, meat production and other performances. Nutritional factors such as excessive or insufficient nutrition adversely affect the entire body function. Grazing animals in arid and semi-arid regions is generally subjected to periods of under-nutrition during extreme hot environment due to non availability of feed and poor pasture conditions caused by lower availability of nutrients, which in turn results in low productivity. The animals suffer severe nutritional stress in the dry season when the natural pasture is of low nutritional value and usually in scarce supply. During this time of the year, animals also waste a lot of energy, as they must walk long distances in search of food and water. As a result of these dry-season and adverse conditions, animals lose weight, body condition, and have low milk yields, low conception rates and increased calf mortalities, all of which culminate into heavy economic loses to the small holder farmers.

It is well documented that under nutrition affects reproductive function in ruminants at different levels of the hypothalamus-pituitary-gonadal axis. The manipulation of reproduction using nutrition is an inexpensive management tool to control ovulation rate and litter size particularly in low cost, extensive production systems in marginal environment such as the semi-arid regions of the world.

Issues to be addressed

In view of meeting the increasing demand for livestock products, these issues are to be addressed on the top priority.

Lack of precise emission data

Having reliable and precise estimate for enteric methane emission in the country is first and foremost pre-requisite for attempting the enteric methane amelioration. If we are not accurate about the methane emission from Indian livestock, there will always be an ambiguity about the claims of reduction.

Limited in animal studies data

Most of the research to evaluate different approaches has been undertaken under in vitro conditions and in vivo studies are very limited where mitigation approaches have been tested for the confirmation of in vitro results in live animals. In vitro results cannot be extrapolated as such for quantifying the absolute emission or reduction from the animals. Conducting in vivo studies are cumbersome, expensive and demands lot of skills and therefore, researchers nowadays prefer to in vitro studies which do not have any consideration for the factors such as intake, microbial adaptation, diffusion of end metabolites etc. For example, in vitro study at National Institute of Animal Nutrition and Physiology, Bangalore demonstrated a significant reduction in methane production with 2.5% tamarind seed husk supplementation; however, this particular level failed to achieve significant reduction in follow up in vivo study in crossbred cattle (Malik et al., 2016, unpublished).

Seasonal variation and instant feed shortage

This is one of the important aspects, which are generally ignored while anticipating the methane emission from Indian livestock. Most of the methane emission database in the country developed on the basis of livestock population, dry matter requirement, factor for methane emission per unit of intake etc; this system provide a faulty estimate as there is no consideration for seasonal variation in fodder availability as well as the animals which are hardly fed to the apatite. Therefore, it is the high time to work out the month wise emission from Indian livestock.

Low productivity of the livestock

It is proved in many studies that enteric methane emission is negatively correlated with animal productivity and it is highest at maintenance level. As the production level goes up, enteric methane emission from livestock proportionally declines. Unfortunately, the low productivity of Indian livestock is one of the major issues accountable for high emission. This attribute needs our urgent attention to grade up our livestock using conventional breeding approaches to improve the profitability of stake holders.

Complex microbial ecosystem in the rumen

The rumen is said to be a mini-microbial world where highly diverse rumen microbes reside in a syntropic fashion. Rumen microbes are highly dynamic, variable and adjust themselves to the dietary alterations and productivity of livestock. Recent studies suggest that the microbial profile of the individual animal may not be even same throughout 24 h. These microbes worked in an inter-dependent way and selectively targeting one specific group of the microbe through interventions may disturb the whole microbial community and their functions. Therefore, we should have to have deep understanding of the ruminal microbes, their substrate requirement and functions before attempting any alteration.

Sustainability issues

The elasticity of the ruminal microbes, their adaptability and vulnerability of the specific microbial community (whole Vs partial) to the approach under investigation are deciding factors for the sustaining the methane reduction level. Unfortunately, no systematic data is available in the country where enteric methane mitigation approaches have been tested for a quite long time. In many studies, it is proved that after some time the animal get back to the normal level of emission if methanogen community is not fully targeted.

Confinement of research

So far whatever approaches have been developed through in vitro & in vivo studies are confined to the organized research institute or universities and no efforts has been done to validate and popularize the approaches in field conditions. The overall adoptability of Indian farmers to newer agricultural technologies/approaches is very poor. To the best of our knowledge, we have not seen any farmer/farm feeding the animals for reducing methane emission or saving biological energy that otherwise lost in the form of methane. Recently, National Dairy Development Board (NDDB) has initiated ration balancing programme in the field conditions and measuring the impact of balance feed on enteric methane emission.

Inter-disciplinary approach

Studying different rumen microbial community structure, elasticity, metabolic pathways, and adaptation mechanism requires the experts from different disciplines such as animal nutrition, microbiology, biotechnology, synthetic Biology, bioinformatics. These microbes should study in long term without changing diet and ambiance.

Lack of front-line demonstration

Despite sufficient in vivo studies in the country, there is hardly any strategy being followed by the livestock keepers for the purpose of methane reduction and saving biological energy. The reason for this could be the lack of frontline demonstration in field conditions and therefore, the stakeholders are not aware about the approaches and intended purpose. It is general perception that the adoptability of newer approaches among the farmers is very less, which could be improved to some extent by frequent front-line demonstrations.

Region- & species-specific ameliorative approaches

India is a vast country possesses quite variable weather conditions. There are region specific breeds of livestock, which are quite adaptable to the local conditions. The crossbred and exotic breeds are more prone to the stress than the indigenous livestock when exposed to same climatic conditions. The research suggesting region specific ameliorative measures to counteract the adverse impact of heat stress on livestock in a particular region is redundant and needs to be studied for developing breed/region specific ameliorative approaches.

Conclusions

Livestock is an integral component of agriculture that supports the livelihood of millions of small and marginal farmers. There are many continents where production potential of livestock is not yet fully exploited. These countries may be instrumental in fulfilling the increased demand of livestock product in future. However, large enteric methane emission and heat stress are two major issues associated with livestock production and need immediate attention for sustaining the productivity and minimizing the contribution of livestock to global warming.

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GREEN FODDER PRODUCTION AND CONSERVATION

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

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. Providing irrigation at regular intervals 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 31are fairly tolerant to drought and can also withstand temporary water logging 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 one cut for fodder, ratooning can be done 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 forperennial varieties like COFS-29 &31.
Maize - African tall, APFM-8, J-1006 and VL-54 Composites like Vijay, Moti and Jawahar	40kg 30 x 15 cm	75-90 (late) 60-75 (early)	350-550
Bajra - Giant bajra, BAIF Bajra-1, AVKB-19, Deenabandhu & Co-8	10kg 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	25kg 30 x 15 cm	60-80	150-200
Lucerne - Anand-2 and 3, Type-9, RL-88 and Co-1	15kg 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, 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. 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 start up 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.9, 500. 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 five weeks time. 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 holderscan prepare silage in 100 kg polybags or 210 liter capacity plastic drums. Drum silage method was testedin 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 0.8 liters 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 two decades, several technologies in the form of high yielding varieties, crop production as well as protection technologies have been developed. 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.

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NUTRITION IN IMPROVING REPRODUCTIVE EFFICIENCY IN DAIRY ANIMALS

N.K.S. Gowda, D. Rajendran, S. Selvaraju and D.T. Pal
ICAR- National Institute of Animal Nutrition and Physiology, Bangalore
E mail: nksgowda@rediffmail.com

Introduction

Improved production potential through cross breeding program increases production stress in dairy animals which affects the conception rate. Nutrients are drained during milk production and creating increased nutrient demand for reproduction. Animals divert their intake nutrients to maintenance, production and reproduction in that order. If any minor shortage in nutrients, the reproduction is the first function that got affected. In India various feeding systems are being followed in different agro-climatic condition due to variation in the availability of feeds and fodder. Those animals are fed excess quantity of protein rich diet for higher milk production which leads to repeat breeding. On the other hand in rural areas, the animals are fed locally available feeds and fodder comprising primarily of crop residues that are low in nutrients and digestibility leading to under-feeding. There are a multitude of factors affecting reproduction of dairy animals which include shortage of feeds and fodder, lack of few nutrients in the diet, improper feeding, excess feeding in peri-urban dairies and organized farm, breed variation, species variation, climatic condition, availability of insemination services and lack of awareness of farmers on feeding and reproductive behaviour of dairy animals. To maintain reproductive efficiency in dairy animals, adequate feeding at the right time in one hand and also to overcome the production stress in another important factor. Reproductive behaviour of cattle and buffaloes varies, the latter shows silent estrous which is often goes unnoticed by the farmers. Energy, protein and minerals especially trace minerals and vitamins play a major role in animal reproduction. A profitable dairy must follow the thumb rule of a calf per year per cow. The major function of nutrients on reproduction is illustrated in table 1.

Milk production and fertility

Genetic correlations between milk yield and reproductive measures in dairy cows are unfavourable. This suggests that successful selection for higher yields may have led to a decline in fertility. Field data on more than a million cows recorded by National Milk Records in the UK showed conception to the first service was 60.8% in 1997 and 52.3% in 2000. Although such studies in large populations have not been reported in India, limited studies and sporadic reports indicate the situation to be not different from other countries. Study from ICAR-NIANP revealed that 21% of the animals had reproductive disorders. Of which, repeat breeders (51.5%) were predominantly high, followed by post-partum anestrus (22.8%), delayed puberty (15.74%) and silent heat (2.4%). The fertility management must start from the stage of calf, heifer for attaining puberty at right stage.

Table 1. Functions of nutrients on reproduction

Nutrients	Reproductive function
Energy	Growth and development of reproductive organs Deficiency -prolonged postpartum anoestrus in cattle and buffaloes Resumption of ovarian activity Development of gonadal organs Hormone synthesis and release Excess intake – low conception rate (Fat Cow Syndrome)
Protein	Deficiency - delayed puberty Deficiency - Cessation of oestruscycle Excess intake – low conception rate and repeat breeding
Calcium	Uterine muscle contraction, uterine involution, maintain uterine muscle tone
Phosphorus	Maintenance of oestrus cycle
Zinc	Wear and tear and of uterine epithelium Maintenance of semen quality
Copper	With 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

Chromium	Follicular maturation and LH secretion (?), secretion of pregnancy specific proteins in uterus
Vitamin A	Tissue regeneration, anti-oxidant, steroidogenesis
Vitamin D	Ca/ P homeostacis, foetal growth
Vitamin E / Se	Anti - Oxidant

Feeding of calf

Colostrum is the birth right of every calf soon after it is born. It should be fed at 1/10th of birth weight till 4th day. Later whole milk should be given at 1/10th of body weight from 4th day up to 15 days of age. From 15 days onwards proportion of milk can be reduced to 1/15th of body weight and a small quantity of calf starter can be offered along with the milk. Calf starter is a feed mixture; containing high quality feed ingredients for supplying energy (72-74% TDN) and protein (22-24% CP) to the calf. The quantity of calf starter should be increased gradually as per body weight and growth rate (approx. 50 gm/week). From 25 days onwards, milk can be fed at 1/25th of body weight and offered along with 100 gm calf starter. Calves should be introduced to leafy green fodder in their early life (after 25 days age), so they start nibbling and their quantity should be increased gradually for the faster development of rumen and optimum growth. The calf can be fed daily 2-3 kg of green vegetation and if good quality tender green fodder is available, calf starter quantity can be reduced. Milk should not be given after 60 days of age and quantity of green and dry fodder/hay and concentrate mixture should be increased.

Table 2. Suggested composition of calf starter

Sl No.	Ingredient	Quantity (kg)
1	Yellow maize	50.00
2	Linseed meal /soybean meal/groundnut cake	35.00
3	Gingelly cake	9.00
4	Molasses or Jaggery	5.00
5	Calcite powder / lime stone powder –Grade I	0.40
6	Dicalcium phosphate	0.25
7	Mineral mixture without common salt	0.20
8	Iodised common salt	0.10
9	Vitamin premix	0.05

	Total	100
	C P (%)	24%
	TDN (%)	74 %

Feeding of heifer

After 60 days of age, the calf can be soley on green fodder and concentrate mixture. The dry matter requirement (2% of body weight) and other nutrients can be met with combination of 70-100% fodder and 10-20% concentrates mixture or individual feed ingredients. If sufficient greens are not available, along with dry fodder or hay, amount of concentrate mixture should be increased. Good quality mineral mixture should be supplemented along with concentrate mixture. Hay prepared from legume fodders are most preferred to replace concentrate mixture.

Reproductive problems

Repeat breeding

The animals are classified as repeat breeders if the animal did not conceive within 3 inseminations in spite of regular cycling with clear mucus discharge. Under village conditions, among the reproductively problematic animals, around 52% of the animals were found to have repeated breeding conditions. The repeat breeding condition may be due to fertilization failure or early embryonic death. The fertilization failure happens if the animal is inseminated with poor quality semen, insemination at the inappropriate estrus, poor nutritional status, etc. Early embryonic mortality happens in animals with hormonal imbalance, fertilization of aged gametes (insemination too early or too late in the estrus), poor quality gametes, poor nutritional status, etc. The hormonal imbalance was observed in the majority of the animals (54%) surveyed under village conditions.

Postpartum anoestrus

The postpartum animals are expected to show estrous symptoms within 60 days and get conceived within 90 days after calving for maximum productivity. If the animal did not show heat symptoms even 90 days after calving, the animals are classified as postpartum anoestrus animals. Among the surveyed animals, around 23% of the animals were found to have postpartum anoestrus condition.

Puberty

The calf attains puberty at the age of about 12 to 15 months in case of crossbred cattle. The age at maturity may vary from 2 to 3 years in indigenous cattle and buffaloes. The animals were considered as delayed pubertal, even if the heifer did not show visible symptoms of estrus at 2 years of age in case of cattle and 3 years in the case of buffalo. Among the surveyed animals, around 16% of the heifers were found to have delayed pubertal conditions. In addition to age, the bodyweight of the animal plays a major role in the attainment of puberty. Thus, good and adequate nutrition during the growing phase is very important for attaining optimum body weight, which is characteristic of the breed. Adequate dietary energy through various internal mediators and messengers prepares the hypothalamic-hypophyseal-gonadal axis to synchronize its activities for proper feedback that is essential for initiation of cyclicity. As such in buffaloes, delayed puberty is an inherent feature and efforts are being made to find out causes and strategies to advance the age at puberty.

Silent heat/Oestrous detection

In dairy animals, heat detection and timing of insemination are the most critical determinants of successful conception. Reports show that up to 50% of modern dairy cows have abnormal oestrous cycles postpartum, resulting in increased calving to first insemination intervals and decreased conception rates. Another report states that the percentage of oestrus animals that stand to be mounted has declined from 80% to 50% and the duration of detected oestrus has reduced from 15 hto 5 h over the past 50 years. A number of physiological events also affect the expression of oestrus. Firstly, high producing dairy cows(≥39.5 kg/day) have shorter oestrus (6.2 h *vs.* 10.9 h), less total standing time (21.7 s *vs.* 28.2 s) and lower serum oestradiol concentrations (6.8 pg/ml *vs.* 8.6 pg/ml) compared to lower producing dairy cows (<39.5 kg/day). Poor expression of heat and difficulty in detection of estrus is more serious problem in buffaloes. In India, approximately 25-30% of the animals are inseminated at the wrong time. i.e. the animals are not an inappropriate stage of estrus. In order to improve the conception rate, the animals can be inseminated at the right time using synchronization with fixed-time AI program. Therefore more attention and new tools to detect estrus to ensure insemination occurs at the correct time are needed. Though many devices/methods like milk progesterone estimation, mount detectors, activity monitors, are available for the detection of heat, proper maintenance of individual animal records with history sheets definitely improves the efficiency of heat detection. In order to avoid heat detection issues and overcome silent estrus, fixed time AI with several protocols are available with GnRH and $PGF_{2\alpha}$ as the principle components and introduction of other additional substances like the progestogens and oestrogens into the protocols improved the conception rate.

Major causes of reproductive problems

Energy

Optimum energy balance is vital for hormonal balance and coordination of reproductive events. The requirement of energy is highest during early lactation. Generally energy requirement is met through a combination of dietary intake and mobilization from body reserves. The cow soon after parturition cannot consume the required quantity of feed to commensurate the requirement due to hormonal and stress factors, however the energy need will be maximum to support milk yield. To achieve this available body fat will be mobilized resulting in negative energy balance for few weeks till the cow consumes required quantity of feed. The onset of ovulatory estrous cycle must occur during the first 2-3 weeks of lactation for desired fertility. The negative energy balance status delays the resumption of ovarian activity and thereby lower fertility. During negative energy status, there will be increased lipolysis with more ketone bodies, low glucose and insulin level in blood. This metabolic shift is the main cause for suppression of increase in leutinising hormone (LH) pulse frequency that is vital for growth of follicles. Low glucose and insulin levels are the primary signals influencing the release of gonadotrophin releasing hormones (GnRH) at central nervous system.

Protein

Protein deficiency and reproduction

The importance of protein in reproduction is well documented. Several hormones like gonadotrophins are peptides in nature and hence require a quality protein in the diet of animals. Often it is a usual practice of dairy farmers to feed more protein to increase appetite and milk yield. Through this offers some immediate benefit, it is not a sustainable approach. The protein in feed are degraded in rumen and converted to ammonia which is used for microbial protein synthesis. Hence a balance of degradable and undegradable protein in the diet is very important, as the latter is more valuable in terms of availability of amino acids at gut level. Feeding high protein diets with more degradability at rumen is not advantageous because of the higher release of ammonia resulting in increased blood urea levels. This could be compounded when the energy intake is deficit. Higher blood urea level is detrimental to uterine environment. Increased ammonia / urea in blood can cause disturbance in intermediary metabolism of glucose/ lactate resulting in impaired endocrine and luteal functions. Protein should never be fed in excess of the requirement and ration should be formulated to provide adequate rumen undegradable protein during peak lactation. The crude protein content of ration can range from 14 – 20 % depending on the level and stage of milk production, of which 40% should be rumen undegradable. In commercial farms, provide high plane of nutrition may lead to excess protein consumption which in turn causes reduced fertility. In tropical countries, puberty is delayed in grazing cattle and buffaloes due to lack of protein content in grazing land especially in fallow grazing land. Deficiency of protein or alteration of energy to protein ratio resulted in delay in oestrous cyclicity. Loss of body weight at postpartum at the extent of 15 % can lead to infertility in dairy animals.

Cholesterol

As per the survey results from ICAR-NIANP, the HDL cholesterol levels were significantly lower in animals with delayed puberty. Only the HDL cholesterol from the blood can be transported through the blood-follicle wall barrier to the follicular fluid and could be the source of cholesterol for steroidogenesis of the granulosa cells. The HDL cholesterol as compared to LDL cholesterol is also found to be higher in follicular fluid of an estrogen active follicle. The low level of HDL cholesterol in delayed pubertal animals indicated the importance of HDL cholesterol in follicular steroidogenesis and onset of puberty and also for the expression of estrous symptoms. The lowered HDL cholesterol coupled with a low BUN in the plasma would have affected folliculogenesis and steroidogenesis in the delayed pubertal animals. Presence of HDL cholesterol may initiate better follicular growth resulting in the onset of estrus in delayed pubertal animals and enhance estrous expression in silent estrus animals.

Micronutrients

Relationship between reproductive functions and micronutrients has been well established. The requirement of micronutrients may change with the physiological state of the tissue during reproductive cycling and pregnancy. Borderline nutrient deficiencies may be manifested as impaired fertility before clinical symptoms are apparent. Optimum function of reproductive tissue may be limited by nutritional deficiencies at critical periods including puberty, parturition and peak lactation. Specific mineral and vitamin requirements for optimal reproduction in modern dairy cattle have not been fully defined during the period of reproductive cycling. 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. The research conducted at NIANP, Bangalore on area – specific mineral mixture has shown highly promising results in improving health and reproductive status of dairy cattle in field conditions.

The 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 study also revealed that the majority of the postpartum anestrus animals were deficient in Mg and Zn. The plasma minerals such as Ca and Zn were significantly lower (p <0.05) in reproductively problematic animals as compared to normal animals. The silent heat animals were found to have higher mineral deficiency i.e. Ca, 88 % (8/9), P, 66.7 (6/9), Mg, 66.7 (6/9), Zn, 77.8 (7/9) and Cu, 44.4 (4/9).The low Ca levels in silent estrous animals may be due to depletion of blood Ca in lactating dairy cows. The deficiency in Ca is responsible for milk fever, reduction in muscle contractility which in turn affects rumen function and lower nutrient intake, thus leading to negative energy balance and poor uterine involution. P is associated with energy metabolism and deficiency may lead to delayed onset of estrus in postpartum animals. P is also necessary for a cellular process such as signal transduction and the deficiency leads to irregular estrus that in turn leads to delayed puberty, silent heat. The Ca and P levels in the body fluids are regulated by various hormones including Vitamin-D. Parathyroid hormone (PTH) regulates the Ca absorption by stimulating bone re-absorption and by enhancing the intestinal absorption of Ca and P. Low calcitriol (Vitamin D3) is also responsible for decreased Ca absorption.

Interestingly, more than 60% of the reproductive problematic animals in India were found to have Mg deficiency suggest that Mg is an essential mineral for optimum reproductive efficiency. Deficiency of this mineral might lead to spasms in the fallopian tubes and thus may affect gametes and embryo transport in the reproductive tract resulting in either fertilization failure or early embryonic death. Thus Mg deficiency in dairy animals may lead to repeat breeding condition. Mg deficiency increases cortisol levels in the blood and increases stress to the animals. A study in the buffalo reported a higher level of Mg in the smaller follicles favor the follicular cell mitosis. In superovulatory animals, the good responders had high levels of plasma Mg suggesting the positive influence of Mg to hormonal treatment and follicular function. The increased Mg in the uterine fluid than serum on day 6 and 8 of estrus indicate the critical role of Mg during a certain window of estrous cycles. A strong positive correlation was observed between Ca and Mg and the relationship between Ca and Mg may also be determined based on tissue requirement. In periparturient cows, the lower Ca level is associated with lower Mg level.

The Zn is an important mineral required for sexual maturity and plays a role in repair and maintenance of the uterine lining. The Zn is essential for prostaglandin synthesis and proper functioning of the uterus and deficiency of Zn leads to embryonic loss. It is associated with carbohydrate and nucleic acid metabolism and protein synthesis. Repeat breeding in Zn deficient animals may be attributed to early embryonic death caused by the unfavorable uterine microenvironment. Zn deficiency in 70% of repeat breeding animals and >70% in delayed puberty and silent heat animals suggest that Zn is a critical element for optimum reproductive efficiency. The study suggests that the macro and micro minerals deficiency under field condition are the major possible causes of repeat breeding. Also, the northern region, where the animals had less mineral deficiency was associated with lower incidence of repeat breeding.

Copper is a necessary component of antioxidant enzymes such as Cu-Zn-SOD essential for maintaining tissue integrity and optimal reproductive efficiency. Trace elements like Cu and Zn are the components of biomolecules viz., ceruloplasmin and superoxide dismutase and their deficiency would lead to lowered antioxidant activity and immune response. The Cu-Zn has a role in regulating reproductive hormones such as progesterone and estradiol for augmenting reproductive efficiency. Cu-Zn SOD is involved in the regulation of cell functions such as progesterone production from the luteal cells. Altered steroidogenesis in Cu and Zn deficient animals might be the reason for poor estrous expression or silent heat. The Zn deficiency leads to retained placenta, embryonic death and irregular estrus.

Feeding strategies for optimum fertility

The feeding management 30 days prepartum to 30 days post partum is critical for optimal milk yield, health and reproduction. A sound late pregnancy feeding programme is the key for improved lactation and reproductive performance of cow.

Dry period feeding

The pregnant cow in lactation, need rest for a certain period to allow reserve build-up and meet the forthcoming events of parturition. A dry period of 60-75 days is generally advised. The energy stored during this period can be mobilized to meet the deficit in early lactation. In addition to good quality green fodder, 1-2 kg concentrate is recommended for reserve building. Proper feeding schedule should be adopted to achieve a body condition score of 3.5 in a 1 to 5 scale, during the late pregnancy period. Cows that score 2.5 and less during early lactation will have lower fertility. At least 40 % of the total DM requirement (1% of cow's body weight) should be met through good quality green fodders and the mineral requirement should be met through additional inorganic supplementation. Dry cows should not loose body weight during this period.

Transitional dry cow diets

This diet is designed to shift the cow from traditional dry cow diet (more fiber) to the early lactation diets (high in energy, protein, less fiber). Transitional diets should be fed for at least 3 wk before parturition, so that rumen microbes gradually get adapted to high-energy diets. The transitional dry cow diets should be formulated to minimize the incidence of metabolic disorders during lactation.

Early lactation diet

Soon after calving, it is not possible to meet the nutrient requirement through feeding alone due to reduction in appetite of cow. Hence, it is desirable to increase the grain portion as energy source and at least 20% of the DM intake should be through good quality green fodders to maintain the rumen environment. After 12 week of calving the proportion of grain can be reduced as the cow can consume more of roughage to meet the energy demand. For meeting the energy requirement during early lactation certain additives like propylene glycol (70-100 g / day) can be added in the diet. Supplementation of niacin (3-5 g /day) will also help in improving the rumen environment and appetite of cow. In very high yielding cows feeding of bypass fat (200-400 g / day) will help in early return to positive energy status, thereby signalling the resumption of ovarian activity.

Semen quality

The semen quality is important to improve overall field fertility. Infertility due to bull factors is to the tune of 30%. The male factor associated infertility is due to the presence of suboptimal/incompetent sperm to fertilize and support embryonic development. Regular assessment of semen quality by the field veterinarians at the hospital/dispensary/ field level will help to assess the quality of semen being used for insemination. Such practice may improve field fertility.

Strategies to meet the energy requirement

Impaired energy balance in high producing animals is very difficult to overcome. Maintaining the energy intake at close up cow (21 days prior to calving) and increasing intake rapidly thereafter in fresh cow (calving to 21 days post calving) should be ensured. Ration balancing in terms of protein, energy, fibre is very important and there are specific tools (Feed Chart, Ration balancing softwares) are available for this purpose. It is advisable to consult an expert for making a ration. To increase energy density of the feed, bypass fat is supplemented in the diet. The concentrate is to forage ratio increased in fresh cow diet to meet the energy (TDN) requirement. The crude protein, calcium, phosphorus content of the fresh cow diet is also increased to meet all these required nutrients for milk production. There are reports of supplementation of cereal grain like crushed ragi grain as energy source (@ 1kg per day) for 90 days to crossbred dairy cows during early to mid lactation period reduced the milk urea nitrogen level indicating a positive effect on energy utilization. In small farms, availability of feed and fodder is major concern and it seems to the important factor to overcome negative energy balance. Prepared feed should be more palatable to ensure high dry mater intake apart from denser diet. To increase DMI, the animal should be allowed *ad lib* feeding and ensure availability of feed in the manger most of the time. During the period of negative energy balance, the blood concentrations of non-esterified fatty acids (NEFA) increases, and the insulin-like growth factor- I (IGF-I), glucose and insulin are low. There are reports of beneficial effect of insulin treatment on fertility in repeat breeding cattle.

Table 3. Suggested composition of concentrate mixture for different category of cows

Ingredients (%)	Level of milk production (Kg/day)			
	Low (5-10 kg)	Moderate to medium (10-15 kg)	High (15-25kg)	Very high (elite category) (>25kg)
Grains	18-20	28-30	38-40	45-50
Wheat bran	30-35	20-25	18-20	6-8
Oil cakes	15-18	22-25	28-30	32-35
Rice polish/ Rice bran/gram chunni	15-20	10-15	5-8	3-5
Gram husk	8-12	5-8	3-5	--
Molasses	5	5-7	8-10	10
Urea	0.50	1	1	1
Mineral mixture	1	2	2	2
Common salt	0.5	0.5	1	1
Calcite powder	-	-	1	2
Sodium bicarbonate	-	-	0.5	1
Bypass fat	-	-	1	1.5
Vitamin premix	-	-	0.1	0.1
Chelated trace mineral mixture	-	-	0.01	0.02
CP in concentrate mixture (%)	16-17	18-19	20-22	23-24(50-55% By pass protein)
TDN in concentrate mixture (%)	62-63	64-65	71-72	73-74

Bypass fat

In early lactating high producing animals, energy demand is more and increasing density of feed by supplementing fat up to a certain extent may be possible. If level of fat (ether extract) exceeds 5 % of the diet, it may leading to negative effects on cellulolytic bacteria and in turn cause decreased fibre fermentation. Hence, to avoid suppression of fibre fermentation, supplemented fat may be added in the form of protected fat (bypass rumen digestion). This protected fat digested in the true stomach and subsequent gastrointestinal tract, which meet the energy demand of the animals and improve reproductive performance. Protected fat supplementation to cows maintained on natural feeding practices at field condition improved the milk production and reproductive efficiency in dairy cattle. For cattle, 20 g bypass fat per kg milk yield and for buffalo 15 g per kg milk yield can be mixed in concentrate mixture and fed. However the total quantity should not exceed 200 g for cows and 150 g for buffaloes, to prevent adverse effect of residual free fat on rumen fermentation.

Conclusion

Feeding management during late pregnancy and early lactation holds the key for optimum production and fertility in dairy cows. The cows in last three weeks of pregnancy should be fed diets with sufficient energy, more rumen bypass protein and supplemented with minerals and vitamins. Enough care should be taken to ensure that the negative energy balance does not persist not more than five weeks after parturition. General strategies for improving nutritional status of dairy animals include : Green fodder cultivation and fodder preservation (hay/silage), Enrichment of crop residues with critical nutrients like nitrogen and minerals, Ration balancing and use of bypass nutrients in high yielding animals, Use of area specific mineral mixture and chelated trace minerals in acute deficiency and peak production, adoption of phase feeding as per stage of lactation, use of total mixed ration using local feed / fodder resources.

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MINERAL NUTRITION FOR FERTILITY MANAGEMENT IN DAIRY COWS

D.T. Pal, N.K.S. Gowda and D.K. Dey
ICAR-National Institute of Animal Nutrition and Physiology, Bengaluru
dtpal@yahoo.co.in

The nutritional quality of feeds and forage can have a tremendous influence on the reproductive performance of animals. Cows in the last third of pregnancy or those producing milk have special needs. If these needs are not met, reproduction is the first body function that is sacrificed. High reproductive efficiency in dairy herds is dependent upon good nutrition and management. Infertility is one of the most important economic losses in high producing dairy cows. Though these losses are largely attributed to health related factors such as retain placenta, metritis, anestrous, silent estrous, cystic follicles, repeat breeding and abortions/still birth, poor feeding and management have often reportedly predisposed the cows to infertility causing factors. Today, many people are implicating deficiencies of various trace minerals, inadequate vitamin intake, energy-protein imbalances as major contributors to infertility and poor reproductive performance. Majority of dairy cows entirely depend on voluntary intake of essential nutrients (energy, protein and minerals) from feeds offered or those they obtain through "scavenge" grazing. Most of these feeds are deficient of the required nutrients and it is these deficiencies that are limiting dairy production in the tropics. The situation is worse during the dry season whence animals heavily rely on crop residues. Because of economic reasons, smallholder resource-poor farmers can often not afford to provide nutrient supplements. The prices of commercially compounded concentrates are often beyond the purchasing abilities of these farmers. The current chronic lack of adequate feeds is primarily attributed to lack of sufficient land for fodder production. As a direct consequence, most dairy cows on smallholder vis a vis "micro farm holders" are chronically in poor body conditions. During the dry season, these animals are often too emaciated and are therefore hardly in a good physiological state to exhibit reproductive cycle.

Minerals and reproduction

Minerals are loosely classified as macro or micro minerals depending on the relative amounts needed or present in the body. Macro minerals include calcium, phosphorus, magnesium, potassium, sulphur, sodium and chloride. Cobalt, copper, iodine, iron, manganese, molybdenum, selenium and zinc are considered micro or trace minerals. Rations that contain a high percentage of forage usually supply adequate amounts of calcium but may be low in phosphorus. However, rations high in grain contain adequate phosphorus but may be deficient in calcium and other minerals. Micro or trace mineral deficiencies are associated with soil type and are usually geographically related. Abnormal levels of some minerals such as iron and cobalt do not usually cause a problem with reproduction. Others mineral, including those which follow, can significantly affect reproduction.

The mechanism of mineral-reproduction interactions is not fully understood because of the complexity of neuro-hormonal dialogue. Some minerals act directly on the gonads, while others act through hypophyseal - pituitary - gonadal axis. Elements like Se once considered toxic, is known to improve both male and female fertility when supplemented in organic form as selenomethionine. During reproductive events reactive metabolites of oxygen are produced and are removed through antioxidant process by Se and vitamin E and provide a convenient environment for reproduction. Similarly other trace elements like Cu, Zn, Mn, Cr and I also act as co–factors or activate enzymes and helps in hormone synthesis and hence influence biochemical functions associated with reproduction. Because of their role in the endocrine system and in tissue integrity, minerals have a beneficial role to play in resumption of follicular growth and fertility in dairy cows and buffaloes. The potential for minerals to play a significant role in herd fertility is indisputable. The minerals that affect reproduction in ruminants are generally found within the trace element group, although deficiencies of calcium and phosphorous can also affect the fertility. Reproductive problems are frequently reported in association with trace mineral deficiencies, particularly copper, zinc, selenium and manganese.

Calcium and Phosphorous: Deficiency of Ca may delay uterine involution and increase incidence of dystocia, retained placenta and prolapse of uterus. Excess Ca may impair reproductive function by causing secondary deficiency of P, K, Mg, Zn, Cu and other trace minerals by inhibiting their absorption in the intestine. Calcium-dependent mechanisms are involved in steroid biosynthesis in the tests, adrenal glands and ovaries. Calcium plays a role in the utilization of cholesterol by mitochondria or by stimulating the conversion of pregnenolone to progesterone. Phosphorus is often associated with reproductive abnormalities in cattle although infertility due to P deficiency is usually manifested after other signs are readily apparent. Phosphorus deficiency induces lowered conception rate, irregular estrus, anestrus, decreased ovarian activity, increased incidence of cystic follicles and generally depressed fertility. The involvement of P in Phospholipid and c-AMP synthesis may be a key to its effect on reproduction.

Zinc and Copper: Zinc deficiency in dairy cows has been postulated to weaken the skin and other stratified epithelia as well as reducing the basal metabolic rate following infectious challenge. Zinc is a co-factor for many proteins and enzymes involved in acute phase response to infection and inflammation. Because the mammary gland is a skin gland, it is likely that zinc will have a positive role in its protection. Skin integrity of the teat has been shown to be specially linked with mastitis prevention. Zinc activates several enzyme systems and is a component of many metallo enzymes. It plays a vital role in hormone secretion, especially related to growth, reproduction, immuno competence and stress. Zinc is also involved in the generation of keratin and in skin nucleic acid and collagen synthesis as well as in the maintenance of normal vitamin A concentration in plasma and in ovarian function. Many animals therefore require supplemental zinc in the diet for normal body function because of either low levels in the dietary ingredients or the presence of antagonistic factors, which decrease the bioavailability of the element. Antagonism might be due to metals ion interactions such as iron or copper. Source of fibre has also been reported to decrease the availability of zinc. Indian studies have shown that repeat breeding and /or anoestrus conditions in livestock could be controlled by improving Cu and Zn nutrition.

Iodine: The need for iodine for the thyroid activity and reproductive failure often is a secondary manifestation of thyroid dysfunction resulting from iodine deficiency in cattle. Fetal development during iodine deficiency may be arrested at any stage and lead to early embryonic death, fetal resorption, stillbirth or birth of goitrous, weak or dead fetus. Hypothyroidism also can reduce gonadotrophin output by the pituitary. Iodine deficiency in bulls is associated with depressed libido and deterioration of semen quality- several studies have revealed that supplementation of iodine has improved fertility, reduced stillbirths, abortions and incidence of retained placenta. Infertility in dairy cattle resulting from irregular or suppressed estrus is often responsive to iodine therapy. Iodine supplementation is necessary in many areas of deficiency but toxic amounts of iodine are not favourable.

Manganese: Manganese is involved in the activities of several enzyme systems including hydrolases, kinases, decarboxylases and transferases as well as Fe-containing enzymes which require Mn in their activity. It is therefore involved in carbohydrate, lipid and protein metabolism. It is also needed for bone growth and maintenance of connective and skeletal tissue. Mn also plays a role in reproduction and in immunological function. Mn deficiency results in abnormal skeletal growth, increased fat deposition, reproductive problems and reduced milk production.

Selenium and Cobalt: Selenium is a semi-metal that is very similar to sulphur in its chemical properties. It is an essential component of glutathione enzyme system, and a deficiency of selenium will leave the cell vulnerable to oxidation and increase the requirement of vitamin E. It has therefore been usual to supplement in the diets of all classes of animals, because of its antioxidant properties. Cobalt is an essential trace element in ruminant diets for the production of vitamin B_{12}, which has 4% cobalt in its chemical structure, by the rumen microbes to meet the vitamin B_{12} requirements of both the ruminal bacteria and the host animal. This means that a cobalt deficiency is really a vitamin B_{12}deficiency that would lead to anaemia.

Amelioration of mineral deficiency

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

Indirect provision of minerals to grazing livestock includes mineral fertilization of pasture and altering soil pH, however this may not be always feasible due to complex soil-plant-animal interrelationship. 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

Feeding of ‘free - choice’ mineral supplements could be the easiest way of supplementing minerals. Alternatively 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 deleterious 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 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 success.

Supplementation through local resources

One of the 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. Some of the unconventional feed resources are also rich in certain minerals. 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.

Impact of some recent trace minerals technologies on animal health and production

Trace minerals are essential for dairy cows and other livestock species and inadequate intake of trace minerals may result in lower reproductive efficiency, poor disease immunity, slower daily gains, and poorer feed conversion. Recently organic minerals sources (chelated minerals, nano minerals, trace minerals-enriched yeast) have begun to gain 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 and decrease of metals in environment.

Chelated minerals

Studies observed that organic trace minerals improved immune response in dairy cows and calves, and also improved milk yield and reproductive performance. Pal et al. (2010) reported that the bioavailability of copper (Cu) and zinc (Zn) and their tissue accumulation was higher in ewes supplemented Cu and Zn from organic than inorganic sources. There are report that supplementation of Zn with glycine chelate improves the growth performance of pigs. Due to higher bioavailability of organic trace minerals, it is suggested performance and concentration of minerals in tissues could be achieved by supplementing less minerals from organic sources.

Nano Minerals

Nano Zn has been reported to reduce somatic cell count (SCC) in subclinical mastitis cow and improved mastitis conditioned with increase in milk production than other conventional ZnO sources. Supplementation of ZnO Nano particles (NP) had improved milk production in subclinical mastitis animal thus can be used as a preventive as well as curative agent. 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 in animal without the fear of antibiotic resistance and residues.

Selenium-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. Research studies suggest that supplementing trace minerals (Cu, Zn, Mn, Cr, Fe and Se) from organic sources especially from chelated or nano forms or encapsulated forms of Cu, Zn, Fe and Se-yeast have major impact on animal health and production. Hence, there is scope to improve animal health, production and reproduction through better bio available micronutrients.

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ANIMAL FEED QUALITY AND SAFETY

S. B. N. Rao, Gopi M, M. Chandrasekharaiah, N. M. Soren, S. Anandan, N.K.S. Gowda
ICAR- National Institute of Animal Nutrition and Physiology, Bangalore
E mail: sbnrao@gmail.com

Feed is the major component in animal production system as they alone constitutes 50-60% in milk production, 70-75% in poultry egg and meat and about 75-80% in swine production. Under these circumstances, the quality of feed fed to the animals is more important not only from economical point of view but also from consumer's side to provide wholesome product. The quality of feed is assessed by its nutritional value, particle size, colour, its safety after consumption and microbial quality. Among these, the nutritive value and microbial quality is more important and is the case for all categories of animals as other factor vary according to the size, age and physiological status of the animals. Various types of hazards can be encountered in the context of feed safety are listed as follows (Table 1). However, it will not be possible to discuss all the issues in the present lecture and broad outline is given to get an idea about this important subject.

Table 1. Quality Control of feed ingredients

Qualitative	Physical characteristics: Color, Texture, Odor and Taste, Particle size (screen analysis), shape, Adulteration, damage and deterioration, bulk density, storage pests, faecal material, hairs etc, spot chemical tests. Biological: Pathogenic bacteria, viruses, parasites and protozoa and mycotoxins produced by molds.
Quantitative	Chemical analysis: Moisture, CP, CF, EE, NFE, ash, Acid insoluble ash (silica or sand), salts, free fatty acids, biogenic amines, urea, and NPN, amino acids. Anti-nutritional factors: Extrinsic: mycotoxins, weeds, insecticide, herbicides, fungicides Intrinsic: allergins, lectins, phytoestrogens, glucosinolates (rape seed), saponins, tannins, ricin, sinapine, gossypol (cotton seed cake), lipoxygenase, trypsin inhibitor, urea. Decomposition and rancidity test: acid value, peroxide value, etc. Protein quality: protein solubility or dispensability, nitrogen solubility, millard reaction product, dye binding, pepsin digestibility, amino acid digestibility.

Assessment of feed quality

Physical evaluation

This is the most practical and easiest way of assessing the quality of feeds. Only raw materials like grains, cakes, brans can be judged by this method. This will be very useful for farmers especially when they buy individual ingredients from the market. This will be useful for taking instant decision on spot purchases.

Colour: Any change in the colour of the feed ingredients gives an indication of the maturity of the grain, storage conditions, presence of toxins, and contamination due to sand, possible use of insecticides/fungicides which gives dull and dusty appearance.

Size: Size of the grains govern its energy value due to the proportional decrease/ increase in seed and its coat. Smaller the grain lower will be the ME value.

Homogeneity: The presence of contaminants like other grains, husks broken grains, weed seeds, infested seeds.

Smell: Smell is the next best indicator. Characteristic aroma will be exhibited by freshly expelled groundnut and mustard cake.

Taste: Each ingredient has a different taste, any change in the taste like bitterness in the grains, soya, sunflower oil meal and groundnut cake indicates the presence of mycotoxins.

Touch: Feeling the raw material will indicate the dryness and moisture content and clumpiness.

Sound: Dry grains on pouring down or biting will produce sound of spilling coins.

Common adulterants in feeds and fodders

Adulteration is defined as admixture of pure substance with some cheaper and low quality substance. Costly feed ingredients like oil cakes and fishmeal, urea sometimes sprayed to increase the protein content. Oil cakes are sometimes mixed with inedible protein meal or husk.

Table 2. Common adulterants in feed ingredients

Feed Ingredient	Adulterant
Groundnut cake	Groundnut husk, urea, non-edible oil cakes
Mustard cake	Argemonamaxicana seeds, fibrous feed ingredients, urea
Soybean meal	Urea, raw soybean
De-oiled rice bran, wheat bran	Ground rice husk, saw dust
Fish meal	Common salt, urea and sand
Mineral mixture	Common salt, marble powder, sand and limestone
Molasses	Water
Maize	Cobs
Rice Kani	Marble and grit

Feed microscopic technique

Feed microscopy is a simple non-destructive physical method technique for rapid identification feed materials and adulterants. This will be useful for feed industries where can take rapid decisions regarding suitability of raw materials for animal feeds. Feed microscopy uses two different techniques.

Table 3. Detailed microscopic observations for feed ingredients

Ingredients	Microscopic Observation
Common Feed Ingredients	
Cottonseed meal	Depending up on decortications, they contain hull fragments, twisted cotton fibers, yellowish brown red chunks of kernels.
Groundnut meal	Good quality meal shows small pink colour skin fragments.
Soybean meal	Solvent extracted meal particles are irregular and flat in shape with round edges. They appear translucent, having a glazed or waxy surface, and varying colors from cream to pale reddish brown. Texture is hard and brittle. Seed coat and hour glass or column cells are the most useful characteristics in identifying soybean products
Mustard cake	Particles are looking typically reflecting yellow coloured oil globules which are not appreciated when the same has been extracted.
Copra meal	The meal fragments range from white to yellowish-brown in color, lustrous

	in appearance, irregularly shaped, the testa is fluffy with brown-black portion. Tubular-like cell structures on the meal particles can be seen. Shell fragments are brown-black in color, irregularly shaped with rough facets. Endosperm is semi-transparent, having large colorless, straight, thin walled cells with color less oil globules inside.
Broken rice	White translucent particles.
Rice polish	Yellowish to light brown, greasy, curly, thin and small flakes.
Salt	Appears spherical or cuboid shape.
Wheat bran	Appear as amoeba like structures with white patches of starch.
Deoiledricebran	Fine longitudinal striations compared to paddy husk.
Adulterants	
Paddy husk	Scaly with longitudinal striations and yellowish.
Sand	Granular, crystalline or bead. Light brown to translucent, don’t break under pressure
Urea	Shiny, needle like crystalline appearance cracks on pressure
Sawdust	Typical serrated edges and thick walls
Mineral salts	Presence of crystalline structures and colour in case of copper and cobalt
Brick powder	Lack of crystalline structure and big particles compared to mineral salts

Chemical evaluation

Chemical analysis is the starting point for determining the nutritive value of feed. The methods used for analyzing feeds are called proximate analysis. The principle of analysis is to separate the feed components into groups or fractions in accordance with their feeding value. The various fractions are dry matter, total protein, ether extract or fat, crude fiber, ash and nitrogen free extract. The proximate analysis suffers from limitations as some components are in excess or missing. The proximate analysis does not include many chemical factors that are important in feeding today. The ash gives no indication of the chemical elements or deficiency or excess of particular essential mineral element. The method also does not include vitamins. Still it is the preferred method of analysis in many feed analytical laboratories.

Table 4. Various proximate analysis procedures and their limitations

Component	Target principle	Contains	Missing	Excess
Moisture	Water	Water	None	None
Crude protein	Protein	All N containing compounds	None	Includes non-protein nitrogen
Crude Fibre	Fibrous Matter	Cellulose, part of lignin	Hemicellulose, part of lignin and acid-insoluble ash	None
Nitrogen-free-extract	Soluble carbohydrates	Soluble carbohydrates, hemicelluloses and acid insoluble ash	None	Hemicellulose, lignin and acid insoluble ash
Ether extract (Crude fat)	fats, oils and fatty acids	Free fats, oils and fatty acids, chlorophyll, sterols, anthocyanin, carotenoids etc.	Protein bound lipid	Chlorophyll, sterols, anthocyanins, waxes etc.,

Spot tests are available for testing the minerals or inorganic compounds used in animal feeds. By using specific chemicals, it is possible to identify trace minerals like cobalt, copper, iron, manganese, magnesium, iodine, zinc, nitrates, phosphates and sulphates. Spot test for detecting urea: Extract 10g sample with 100 ml distilled water. Pipet 2 ml of standard urea solution and sample extract in spot plates. Add 2-3 drops of cresol red indicator and urease solution and stand for 3-5 minutes. If urea is present, it will form a deep red-purple spreading like a spider web appearance, in contrast to yellow colour of indicator. The test should be read in 10-12 minutes.

Microbial quality

The microbial quality of animal feeds has gained much importance than ever before ever since the occurrence of salmonellosis, coliforms, Campylobacter and Bovine Spongiform Encephalitis (BSE) in the European Union. The awareness on microbial characteristics in United Kingdom since 2001-2002 after epidemic incidence of foot and mouth disease. The animal feeds are being contaminated with microbes (bacteria, virus and yeast/fungi) of different origins. However, the occurrence of fungal infestation in grains/forages is matter of concern due to its ubiquitous nature and also their secretory products. The incidence of fungal contamination in animal grains and feed stuffs is a regularly reported especially during winter, rainy and hot-humid seasons. The fungal infestation resulted in detrimental effects on almost all animal species worldwide. This detrimental effect of fungal infestation was due to the generation of mycotoxins from certain species and strains of moulds. The microbial contamination of feed might be due to numerous factors such as plant itself, soil from which it grows air of locality, water quality, animals grazing on the pasture and also during the periods of harvesting, storage and processing. Similarly, the environmental contamination with bacteria (Salmonella, E. coli, Listeria, etc.) and viruses (FMD) are commonly encountered in almost all parts of the world.

However, the addition of organic acids such as propionic, butyric acids and also certain phyto chemicals during feed processing or storage had improved the microbial quality of feeds especially against fungal infestations. Effective feed safety programmes should include inspection, testing and monitoring of raw materials, processes and end products.

Emerging threats for feed safety

Melamine contamination in feeds

India has imposed a three-month ban on import of milk and milk products from China due to the presence of a contaminant melamine. Melamine (2,4,6-triamino-1,3,5-triazine) is a heterocyclic compound containing 6 nitrogen atoms and have a very high nitrogen content (66 % N). This is an industrial chemical used in making plastics and fertilizers which can cause kidney stones and lead to kidney failure. Feeds with a high nitrogen content and low level of amino acids are to be suspected of adulteration with melamine. Protein concentrates from unknown origin are to be suspected of contamination with melamine. A hydrolysis product of melamine is Cyanuric acid {1,3,5-triazine-2,4,6-triol $(CNOH)_3$} – is a cyclic trimer of hydrocyanic acid (HOCN). It is a component in various disinfectants, herbicides and bleaching agents. Melamine and cyanuric acid as individual substances do not cause any toxicity but the complex melamine-cyanurate complex, is cause of human and animal health problems. Modern analytical methods are to be used for detection these compounds. Samples are extracted with acetonitrile-water and purified through Solid-Phase-Extraction (SPE) cartridge and subsequent evaporation and injecting in to liquid chromatograph coupled with mass detector (LC- MS/MS). Studies revealed that more than 60 % of melamine was transferred to milk within 30 h of melamine ingestion. However, melamine was not detected in milk after 7 days of treatment whereas; cyanuric acid was not detected in any of the samples indicating no biological conversion of melamine in the cow. However, melamine administration did not affect BUN and milk melamine was transferred mainly to the whey fraction during cheese preparation

Bovine Spongiform Encephalopathy

Bovine spongiform encephalopathy (BSE) belongs to a group of progressively degenerative neurological diseases known as transmissible spongiform encephalopathies (TSEs) associated with a variant form of Creutzfeldt-Jakob disease in humans. TSEs are fatal diseases caused by prions (proteinaceous infectious particle) and are characterized by an incubation period that may range from several months to several years, depending on the host. BSE spreads through animal feed, the main strategy for preventing the establishment and spread of BSE is to prohibit the use of proteins derived from mammalian tissue in feed for ruminant animals. PCR primers for the detection of materials derived from ruminants, pigs, and chickens were newly designed on the basis of sequences of the Art2 short interspersed repetitive element (SINE), PRE-1 SINE, and CR1 long interspersed repetitive element (LINE), respectively which in turn amplified the SINE or LINE from total DNA extracted from the target animals and from test feed containing commercial meat and bone meal (MBM). With the primers, detection of Art2, PRE-1, or CR1 in test feed at concentrations of 0.01% MBM or less was possible.

Genetically modified feeds

In India the first transgenic (Bt Cotton) was cleared for cultivation in the year 2002. Within a span of seven years the area under Bt cotton has gone beyond 7.6 million hectares and it constitutes approximately 82% of the total cotton area of the country. Important States where Bt cotton is grown extensively include Maharashtra (3.13 million hectares- representing almost half of 42% of Bt cotton area in India) followed by Gujarat (1.36 million hectares), Andhra Pradesh (1.32 million hectares), Madhya Pradesh (620.000 ha). In terms of feed safety aspects of GM cotton seed meal, no adverse reports of feeding of cotton seed meal to dairy cows, buffaloes, poultry and fish were reported and Cry1Ac proteins in the milk nor in blood of cows was detected.

Discounting of on account of incriminating factors

In feeds and fodders, various incriminating factors like trypsin inhibitors, phytates, oxalates, glucosinolates, gossypol, tannins are present in feedstuffs in various concentrations. They affect the metabolic utilization of certain nutrients like protein and bind with minerals such as calcium, phosphorus, iron. The common feed stuffs being fed are cottonseed meal, mustard seed meal, tree leaves, paddy straw, napier grass contain incriminating factors. Whenever, they are fed in major quantities, it is required to supplement additional nutrients for getting desired response. However, few factors like cyanogens, pesticide residues like insecticides, herbicides, fungicides and mycotoxins will affect the health of the livestock hence cannot be discounted for nutrients per se.

Hazard analysis critical control points (HACCP)

HACCP is a food safety system first developed by the Pillsbury Co. to reduce the risk associated with the food eaten by astronauts during space flights. HACCP is systems approach which:

- Identifies potential sources of contamination in food production systems.
- Establishes methods for detecting the occurrence of contamination.
- Clearly prescribes what corrective actions will be taken to prevent consumption of contaminated food items. Similar type of approaches needs to be followed to feed manufacturing industries and production farms so as minimize risks involved in the feed safety.

Prevention of feed hazards

Prevention is best method of control. Good agricultural production, manufacturing and sanitary / hygienic practices with adoption of principles of HACCP are must to assure the safety. Suitable varieties of crops intended for animal consumption which are free from natural toxins and resistant to diseases should be developed. Handling and storage practices are to be improved. Use of chemicals should be restricted in agricultural and animal production. Organic production is one of the alternatives to produce healthy foods. The importance of monitoring programs can’t be overlooked in ensuring the feed safety. It is required to have strong base for detection and quantification of toxic substances. Concerted efforts are needed by labs at national and international level to develop fast, simple and low cost analytical methods for testing of all groups of foods. The establishment of standards for MRLs of all harmful substances is the urgent necessity.

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EASY WAY FOR RATION BALANCING OF FARM ANIMALS

D. Rajendran, N.K.S. Gowda, M. Gopi and N. Ramachandran
ICAR-National Institute of Animal Nutrition and Physiology, Bangalore
E mail: rajnutri@gmail.com

Feed accounts for more than 70 % of the operation cost of dairy production. Preparation of least cost ration with optimum nutrient is challenging task to the farmer. Feeding of imbalance nutrient causes one or more nutrient insufficient on other hand one or more costly nutrients excess. Deficiency of one or more nutrient cause less production and lead to more production cost. Hence balanced ration is essential for optimum production & reproduction and reducing the feed cost.Ration balancing tools are becoming more popular among the farmers. There are several ration balancing tools are available in mobile and computer platform apart from self calculating feed chart in printed form. Recently, in Google play stores, NIANP has launched ICAR-NIANP Feed Chart for cattle, Buffaloes and “TMR maker” an excel based software - available through website.

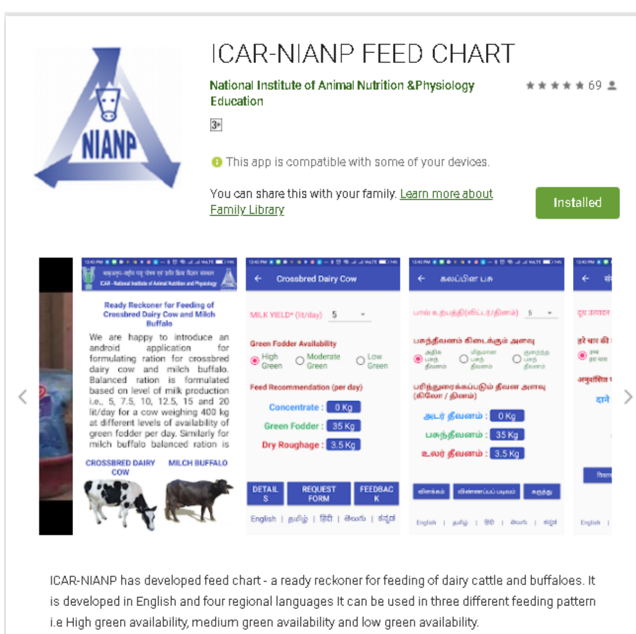

Fig.1. Screen shot of ICAR-NIANP FEED CHART apps available in Google play store

ICAR-NIANP Software

1. Feed Assist
2. TMR Maker
3. Feed Chart on print, and web media
4. Android App: ICAR-NIANP Feed Chart
5. Android App: ICAR-NIANP Small tool for Cattle and Buffalo feed formulation
6. Ration balancing tools for small ruminants

1. Feed assist

"Feed Assist" is an expert system to compute balance ration for dairy animals in least cost basis as per the nutrient requirements of various categories of cattle and buffalo using a choice of the feed resources available. This system has been developed using MS-Access as back-end tool and visual basic as front-end tool. By choosing the feed ingredients and providing the details of the animal with respect to the parameters like, body weight, average daily growth rate and milk yield, the farmer can obtain a balanced diet that gives the details of different ingredients and their proportions to be fed.

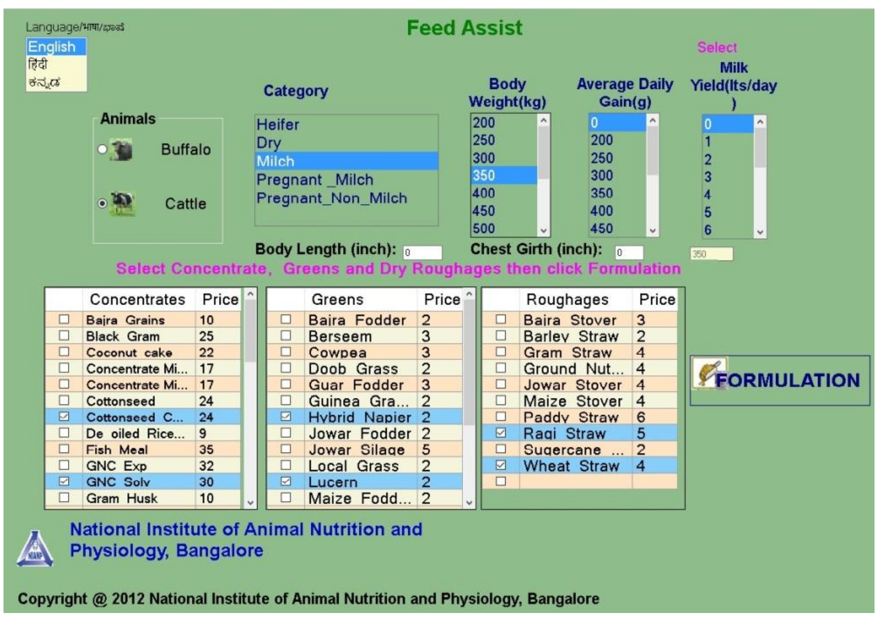

Fig. 2 Screen shoot of First page of Feed Assist

2. TMR Maker (Total Mixed Ration – Maker)

ICAR-NIANP has developed a software programme named "TMR Maker" to optimize the nutrients in the ration of dairy animal. The programme has advantage of cost controlling and optimizing nutrients in the diet. The farmer can formulate the ration by using least cost feed formulation method. This software is easy to use and farmer friendly as well.

Fig. 3. Screen shot of First page of TMR - Maker

What is total mixed ration (TMR)?

All the ingredients (roughage and concentrate) are mixed and offered to the animal per day basis is called as **total mixed ration (TMR)**. It ensures that the concentrate intake is spread uniformly over the day rather than only twice daily as practiced in the conventional feeding system. This enhances the digestibility of roughages, reduces the nutrient loss and thereby improves the productivity and profitability, particularly in intensive system. Preparation of TMR comprising of roughage / forage, concentrate and other supplementary nutrients in required proportion are made into uniform mixture either in the form of mash or pellets / blocks (complete feed). The required quantity of the concentrate, green and dry roughages and supplements Viz. Minerals, vitamins, feed additive can be calculated on least cost basis with optimum nutrient level using **TMR maker**.

However, preparing TMR or complete feed requires machinery (grinder and mixer), which involves investment.

3. Feed Chart

NIANP scientists have prepared farmer friendly tool called as "FEED CHART" for feeding of crossbred dairy cow and buffalo. This will suggest the calculated amount of concentrate; green roughage and dry roughages required per day for 400 kg crossbred cow /450 kg buffalo based on their milk yield. The provision is made for three categories of farmers, viz. farmers having high green grass, moderate green grass or less green grasses. The suggested ration according to milk yield may be followed by the farmer for reducing the cost of milk production.

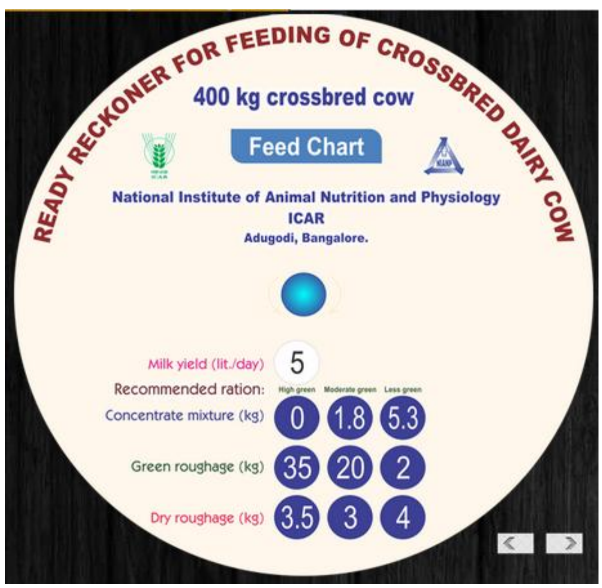

Fig 4. Feed chart for crossbred cow

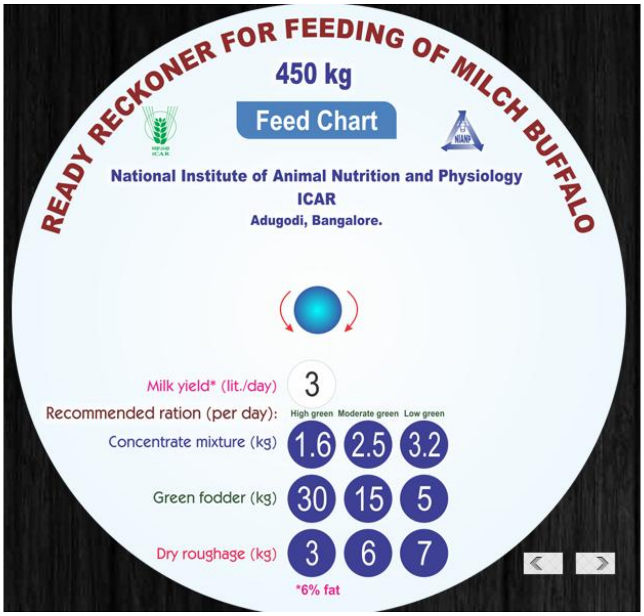

Fig.5. Feed chart for buffalo

4. Android App: ICAR-NIANP Feed Chart

It is available in Android apps Google play stores as ICAR-NIANP FEED CHART. It can be downloaded in any type of android phone and used as offline application. It is available if 5 language and for cattle and buffaloes. It is user friendly and advantage being in local language.

5. Android App: ICAR-NIANP Small tool for Cattle and Buffalo feed formulation

ICAR-NIANP recently launched an Android based least cost feed formulation tool for the ration balancing of cattle and buffaloes. It is developed in two languages English and Kannada. It is a least cost feed formulation tool. Farmers can provide animal data like weight of the animal, milk yield, milk fat %, status of pregnancy. App will calculate the nutrient requirement. Next screen users can select the available feed in the farm, from the list provided in app by select/unselect method. After selection, it will calculate least cost feed formulation and display the amount of east feed ingredient to be fed to the animal every day.

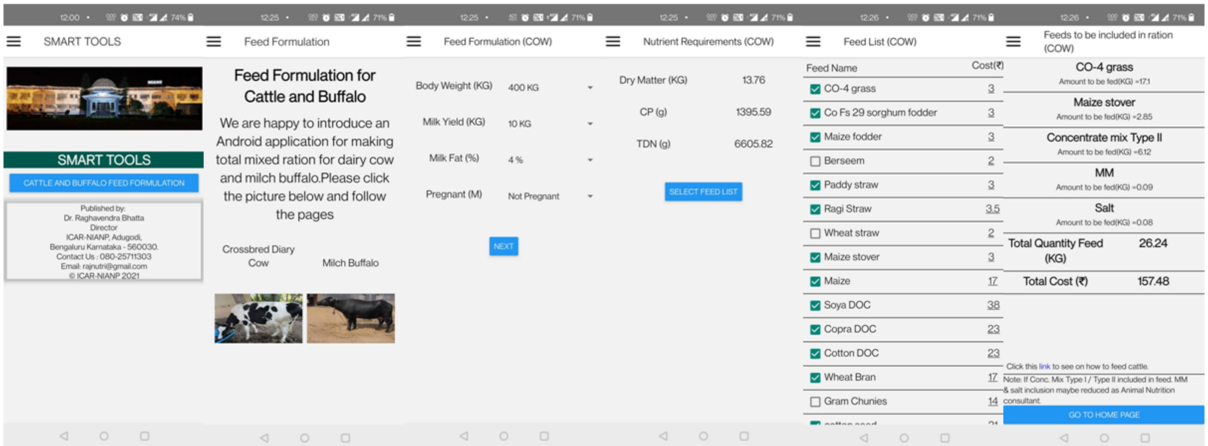

Fig.6. Screen shot of ICAR-NIANP Smart tool available in Google play store.

6. Ration balancing tools for small ruminants

NIANP has developed smart tool for formulation of least cost feed for small ruminants like sheep and goat. Requirement is calculated based on the average daily gain and body weight and feed is formulated on least cost basis.

Fig. 6 Screen shot of first page of Ratio balancing tools for goat.

Management practices to reduce feed cost

- Individual feeding based on body weight, milk production and pregnancy.
- High level of green grass based feeding and low concentrate feeing i.e., High green diet based total mixed ration.

- Green fodder should be chapped to at least one inch thickness and fed to the animal.
- Feeding of total mixed ration instead of separate feeding of concentrate, green and dry fodder.
- Increasing the frequency of feeding at least 4 times in a day.
- Providing ad lib fresh clean drinking water for 24h.
- Energy is more deficient in cattle feeding. Hence energy deficiency has to be taken care.
- Sufficient quantity of mineral mixture feeing is necessary.
- One calf per year per cow to be followed.
- Avoid metabolic disorder viz. milk fever, ketosis etc.
- High grain feeding should be accompanied with sodium bicarbonate.

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FEEDING OF BULLS FOR OPTIMUM REPRODUCTIVE PERFORMANCE

N K S Gowda and D Rajendran
ICAR-National Institute of Animal Nutrition and Physiology, Bengaluru
E mail: nksgowda@rediffmail.com

Nutrition of bulls both during growing and production state is very important for efficient reproductive performance. When young and matured bulls are reared together, some may not get the adequate nutrition and others may get excess. Obviously this creates either over or under feeding within a group, both of which is not desired. Hence, individual feeding management should be followed to avoid over or under feeding at bull station.

Nutrients and feed stuff

Feedstuff selection for feeding of bulls should be based upon the necessity of meeting the nutrient requirements of the growing bull / mature bull and the cost of the important nutrients (energy, protein, minerals). For growing bulls, energy limits growth, thus feedstuffs that contain adequate energy concentrations to support the desired level of growth should be considered. Based on the nutrient content, the feeding stuff may be classified as energy dense ingredients, protein dense ingredients, mineral and vitamin rich ingredients and feed additives.

Energy

Energy is very important in the diet of young, growing and also mature breeding bulls. Immature bulls fed on energy deficient diet will display retarded sexual development and delayed puberty and at times energy deficiency in growing / young bulls will have permanent damage, while energy deficiency can be corrected in mature bulls. In most cases energy dense feedstuffs will be cereal grain or its by-products (maize, wheat, ragi, broken rice, oats) or concentrate mixture. An average ejaculate of the bull semen is about 0.5 g of dry matter. Therefore it appears that nutrient requirements for production of semen is inappreciable compared with requirement for maintenance or growth. The energy requirement of mature bull is just like that of maintenance and activity (exercise) requirement. Excessive fattening of breeding bull reduces reproductive performance. The energy requirement of cattle and buffalo breeding bull is calculated @ 41.04 g of TDN /kg of metabolic body weight ($W^{0.75}$) and presented in Table 1. The TDN requirement for growing cattle and buffalo are also presented in Table 1.

Table 1 Energy and protein requirements of growing male cattle and buffaloes calves

Body weight (kg)	Growth rate (kg/d)	Dry matter (kg)	Energy (TDN) (kg)	Crude protein (CP) (g)
70	0.2	1.6	1.14	287
70	0.3	1.8	1.25	378
70	0.4	1.8	1.36	467
100	0.2	2.6	1.46	309
100	0.3	2.7	1.58	395
100	0.4	2.8	1.70	480
100	0.5	3.0	1.83	562
100	0.6	3.1	1.96	641
100	0.7	3.2	2.08	718
200	0.3	4.6	2.54	446
200	0.4	5.0	2.70	518
200	0.5	5.2	2.87	588
200	0.6	5.2	3.05	655
200	0.7	5.4	3.22	721
200	0.8	5.6	3.40	783
300	0.3	6.3	3.38	512
300	0.4	6.6	3.58	563
300	0.5	6.9	3.79	617
300	0.6	6.9	4.00	675
300	0.7	7.5	4.22	731
300	0.8	7.5	4.44	784
300	0.9	7.8	4.66	836
400	0.4	8.8	4.39	639
400	0.5	8.8	4.63	687
400	0.6	9.2	4.88	733
400	0.7	9.2	5.14	779
400	0.8	9.2	5.39	823
400	0.9	9.2	5.65	866
400	1.0	9.6	5.91	908
500	0.4	10.5	5.14	715
500	0.5	10.5	5.42	762
500	0.6	11.0	5.71	808
500	0.7	11.0	6.00	852
500	0.8	11.0	6.29	896
500	0.9	11.0	6.58	938
500	1.0	11.0	6.88	980
600	0.6	13.2	6.49	886
600	0.7	13.2	6.81	931
600	0.8	13.2	7.14	975
600	0.9	13.2	7.47	1018
600	1.0	13.2	7.80	1059
600	1.1	13.2	8.14	1100

Like underfeeding, overfeeding also has negative effects on reproductive performance. Excess external fat on back of the bull limits the ability to mount or donate semen. Excess fat around scrotum increases the temperature in the scrotal cavity and reduces both sperm production and quality of stored sperm. Over fat bulls are predisposed to musculo-skeletal disorders like osteochandrosis and laminitis. Ideally bulls should be in a body condition score of 6-6.5 out of 9. The entire sperm production cycle from initial creation of sperm from germ cells, maturation in epididymis up to ejaculation of mature sperm in semen takes about 60 days. Hence health and nutrition of bulls for up to 60 days prior to breeding will influence quality of semen.

Protein

Adequate protein is needed to maintain active body condition and to support growth in young bulls. There is also a protein component in seminal fluid and spermatozoal proteins in the form of enzymes are critical for sperm motility and capacitation. Protein deficiency affects young bull’s more than mature bulls and young bulls on a protein-deficient diet will display decreased libido and poor semen quality. Protein requirement for production of semen is inappreciable compared with requirement for maintenance. However, for maintenance of good health and to ensure optimum feed intake sufficient protein must be provided in the diet of breeding bulls, but protein should not be fed more than the required. Feeding more protein could lead to copper deficiency as a result of more sulphur intake. Maintenance requirement of protein for mature cattle and buffalo breeding bulls is calculated as 7.46 g CP/ kg $W^{0.75}$ and represented in Table 2. Requirement of protein for growing cattle and buffalo (Table 1) bulls are presented. Protein feeds can consist of any of the oilseed meals or selected by-products (soybean meal, mustard cake, til cake, coconut cake, and sunflower cake, or dried distillers grains, corn gluten meal). Excess feeding of highly degradable protein sources (groundnut cake, mustard cake, and soybean cake) could cause reproductive disorders due to more ammonia release and higher blood urea formation. Feeding bypass protein to bucks had a positive influence on sexual behavior traits like erection time, total time taken for successful mount, protrusion score and semen quality (mass activity, initial mobility, live, dead abnormal sperms). Bypass protein feeding in Mehsana buffalo bulls resulted in improvement of erection, protrusion score and better semen quality. Reduced service period was also observed in buffaloes fed bypass protein feed. List of most important nutrients and their function are briefed in Table 2.

Table 2. Important nutrients for semen production

Nutrient	Function
Lipid	Testes contain high content of poly unsaturated fatty acids, help in sperm cell viability, maturity and fertility.
Protein	Testicular development from foetal stage, supply of essential amino acids. Deficiency would lead to immature testes, delayed puberty.
Arginine(amino acid)	Biochemical precursor of putrescine, spermidine and spermine which are essential for sperm motility.
L- Carnitine	Conditionally essential amino acid and promote sperm motility, maturation, supply energy to spermatogenic activity, antioxidant and protect cell membrane.
Vitamin A	Helps in spermatogonial differentiation.
Vitamin D	Regulate Ca level in testes.
Vitamin E	Protects sperm from lipid peroxidation.
Vitamin C	Protect from oxidative stress, maintain genetic integrity of sperm.
Folate	Essential for germ cell development, DNA/RNA synthesis, strong antioxidant for oxidative stress.
Vitamin B_{12}	Essential for RNA / DNA synthesis, promotes healthy growth of seminiferous tubule.
Vitamin B_9	Promotes healthy sperm and seminiferous tubule development.
Zn, Cu	Initiation of spermatogenic activity, sperm maturation, enhance sperm motility, regulate ATP system, stabilizes the chromatin.
Se	Se is a component of selenoproteins(L-Selenomethionine, L-Selenocysteine, Glutathione peroxidase), help in cell growth, protective antioxidant, helps in apoptosis and cell signaling system.

Minerals

While all minerals in adequate levels are important to bull health and reproduction, 2 key minerals with a direct effect on bull fertility are copper and zinc. High levels of sulphur, iron and molybdenum could induce copper deficiency. Copper deficient bulls will have reduced libido and low semen quality. In severe deficiency the bull can become sterile due to damaged testicular tissue. Proper zinc nutrition is necessary for maintenance of testicular tissue and sperm production. Low zinc intake results in reduced sperm production and delays sperm maturation. Zinc deficiency also results in reduced vitamin A utilization leading to testicular degeneration, low sperm count and abnormal sperms. A mineral and vitamin supplement should be offered that contains adequate calcium, phosphorus, zinc, copper, iodine and vitamin A, E and selenium.

Green fodder

Similarly, the need for roughage in the diet may necessitate the use of medium to good quality forages to support the desired growth level. The digestible protein in good quality forages can help to reduce inclusion levels of costlier protein concentrates. A variety of roughage sources are fully acceptable as ingredients for bull rations. Common roughage sources include paddy straw, wheat straw, sorghum hay, ragi straw, bermuda grass etc. The selection of hay should be based upon the performance goals for the bull with the objective of meeting the nutrient requirements. Cultivated fodder crops like Napier X Bajra hybrid grass, guinea grass, para grass, berseem, lucerne, hedge lucerne and tree leaves like glyricedia, *Albizia lebbek*, mulberry etc. are suitable for feeding of breeding bull. Pasture is a primary choice for roughage in a bull diet where established pasture lands are available. When pasture is utilized a number of issues need to be considered, including adequate pasture forage availability, intake, and quality to meet the feeding goals. Moldy hay could contain Fusarium mycotoxins like T-2 and zearalenone and would disturb the semen quality and hence should not be fed. There is no single ingredient that will meet the requirement of bulls, but combination of roughage, concentrate, mineral and vitamin supplement and feed additives would make the balanced nutrient for breeding bull.

Precaution while feeding of cotton seed meal and subabul

As per the scientific reports feeding of whole cotton seed (WSC) cake results in increased sperm abnormalities, decreased sperm production, and adversely affect the sexual behavior of bull. The use of WCS for young bulls should be limited. An acceptable recommendation is that bulls are removed off from WCS at least 90 days prior to the initiation of the breeding season. The 90-day removal will allow adequate time for the gossypol to be metabolized and sperm production to occur without the potential negative influence of gossypol. Similarly, feeding of subabul as sole protein diet may cause reduction in libido, individual motility and mass activity of the semen. Hence feeding of subabul should be restricted to 10% of protein requirement.

Organic / chelated trace minerals

Both organic and inorganic minerals may be utilized effectively as mineral sources for bull development. Regardless of the choice to include organic sources or not, the use of well-balanced mineral and vitamin supplement to meet the bull's requirements is the main management consideration. The uses of organic minerals that may result in the greatest benefit include: zinc, copper and selenium. Research reports suggest that fertility was better in bulls fed organic zinc. Selenium is also implicated in sperm viability, quality, and overall reproductive health. The year-round use of organic minerals for bull production is not necessary in case of herd bull. Similar to the overall conditioning period, the use of organic minerals should be implemented 60-90 days before initiation of the breeding season.

Feeding management of breeding bulls at herd level

Pre-weaning nutrition

Traditionally bull calves are maintained on their dam until normal weaning at 3-6 months of age. Normally the plane of nutrition from dam's milk and good quality forage should be adequate for normal growth rate of bull calves. Early weaning or creep feeding (concentrate) can be considered, when the calves' plane of nutrition is less than desired. The progeny tested dams are used to produce superior bull for breeding purpose. During this period the bull is at the dam's side and nutrition during this period is likely adequate to ensure normal growth and development. Exceptions would be indicated when the dam's nutritional environment limits milk production. Creep feeding of potential herd sire bulls is utilized in some instances. Currently, there is little or no data that have evaluated the long-term effects of creep feeding on bull performance. Young bulls should attain 1/2 their mature body weight by 14-15 months of age. Extremely low levels of energy intake early in life delay the onset of puberty. Feeding of excess energy may reduce both semen quality and serving capacity. This is thought to be due to excess fat deposition in the scrotum, insulating the testes and increasing testicular temperature. Nutrient requirement of growing cattle bull and buffaloes (Table 1) are presented.

Post-weaning nutrition

It is better to feed for moderate gain instead of high rates of gain to develop breeding bulls during post-weaning phase. Body condition score (BCS) should be monitored to ensure that the bulls are not being under – or overfed and the yearling bulls should have a BCS of 5.5 – 6.5 on a 9 point scale. Gradual changes are needed when changing diets to more or less concentrated to reduce the possibility of metabolic disorders and impaired breeding performance.

This period of nutritional development should allow the bull to grow at nearly the bull's genetic potential. The nutritional design of many growing programs or bull test station diets is a concentrate based, low-roughage, high-energy diet. The goal of this period is to grow the bulls rapidly, but avoid excessive fat development. The nutritional program should also be designed to avoid digestive upsets or affect soundness. The high-energy, high-plane of nutrition also stimulates the onset of puberty particularly in later maturing breeds. Adequate research indicates that either under- or over-nutrition during this period can have negative effects on bull development, attainment of puberty, and semen quality. Well designed bull test diets or purebred bull breeders with sound development programs should allow bulls to express their growth potential without any deleterious effects on future performance.

Conditioning prior to breeding season

This period is the most important next to the development phase. Not only do growing bulls need this conditioning period, but mature bulls need to be conditioned before entering service during the breeding season. Growing bulls generally have just gone through the development phase which consisted of high-energy concentrate based diet. As such these bulls need to be cycled down from that high plane of nutrition. There needs to be a transition from the test diet or development diet to a conditioning or maintenance diet that is often forage based. The transition to a forage-based diet often occurs when the bulls are losing their teeth, compounding the stress of the diet transition. The conditioning period should be around 60 days. This time frame should allow adequate time for the bulls to adjust to a new diet. For well conditioned bulls this time frame will allow bulls to moderate their fat cover and "harden up," likewise thin bulls will have adequate time to increase their body condition if required. Additionally, the 60-day time frame provides adequate time for the sperm population to turnover and quality sperm to develop prior to the bull entering breeding service.

Nutrition during the breeding season

The conditioning period prior to initiation of the breeding season becomes all the more important. Bulls during the breeding season can lose from 40 - 200 kg of bodyweight. The amount of bodyweight and body condition loss will be influenced by the age of the bull, prior body condition, length of the breeding season, level of activity experienced by the bull, and breed type of the bull.

Nutrition after the breeding season

The bulls after the breeding season likely will need some attention to restore their bodyweight and body condition. The amount of bodyweight and body condition that needs to be replaced after the breeding season can be considerable depending upon how much bodyweight and body condition the bull mobilized. As mentioned previously young bulls and terminal sire type bulls likely will lose more bodyweight. Terminal sire type bulls may require supplemental feeds to regain lost bodyweight because pasture quality may not support the needed performance. Likewise the use of young bulls that still have growth requirements will likely result in greater feed input requirements after the breeding season.

Feeding Management of breeding bulls at semen station

Bulls reared in the bull station at semen bank are exclusively used for semen collection at regular interval. The exotic breed like Holstein Friesian and Jersey are commonly used for cross breeding programme in India. Indian cattle breeds like Red Sindhi, Tharparkar and Kangeyam breeds are used for semen collection. Buffalo breed includes Murrah, Surti and Jafrabadi are commonly used to upgrade local breeds. The elite bull of each breeds are selected and used for semen collection centre at semen bank. Bulls are used continuously without any break of breeding season. The feeding management of bull at semen bank is differing from bulls maintained at herd. The mature bull should be maintained as per nutrient requirement of ICAR (2013) as given in Table 4. Concentrate mixture can be prepared as per example given in the Table 5.

Table 4. Daily energy and protein requirements of cattle/buffalo breeding bull

BW (kg)	**Dry matter (kg)**	**Energy (TDN) (kg)**	**Crude protein (CP) (g)**
350	6.5	3.46	394
400	7.6	3.82	436
450	8.6	4.18	476
500	9.7	4.52	515
550	10.8	4.86	553
600	12.0	5.18	591
650	13.0	5.50	627
700	14.0	5.82	663
750	15.1	6.13	698
800	16.5	6.43	733

Table 5. Suggested ingredient composition of concentrate mixture for matured bull

Sl No	Feed ingredients	Quantity (kg/100kg)
1	Yellow maize	30
2	Wheat bran	10
3	Rice polish	15
4	Coconut cake	12
5	Groundnut cake	20
6	Molasses	9.50
7	Bypass fat	0.50
8	Calcite (Grade 1)	0.50
9	Mineral mixture with chelated trace minerals	2.00
10	Common salt (iodised)	0.50
	Total	100
	CP(%)	16-17
	TDN(%)	67-68
Note: If quality of green fodder in not good, supplementation of Vitamin supplement (A, D,E, B1, B6, Choline) is required		

Regular body score must be performed to avoid over weigh of the bull. The ration should be balanced with energy, protein, minerals and vitamins. Individual feeding is recommended to avoid over weight of some bull and under nutrition of young bull. The DM requirement of individual bull should be calculated based on body weight and require growth rate if required in young bull. Total mixed ration having optimum level of nutrient with proper ratio of roughage and concentrate may be fed (Table 7). Nutrient requirement of mature bull will be calculated (Table 2) as per ICAR (2013) and model example diet is shown (Table 7 & 8). Regular exercise and routine health check up will be the useful to avoid nutritional problem. The common mistake found in semen bank is over nutrition. The over nutrition can cause reduction in reproduction performance. Hence care should be taken to avoid over nutrition among the valuable exotic breeds, more particularly excess protein should not be fed.

Table 6. Suggested nutrient content of concentrate mixture, green fodder and dry fodder

Feed	Dry matter(DM %)	Energy (TDN %)	Crude protein (CP %)
Concentrate mixture	90	65-67	16-17
Green fodder *	20	55-56	7.0-8.0
Dry fodder	90	42-45	3.0-4.0
Legume fodder / tree forage	25	55-57	18-22

Green fodder: maize /sorghum/ bajra /napiers/ rhodes/guinea/jinjiva

Dry fodder: Ragi straw/ jowar straw/ hay/ maize straw /hay

Table 7. Example of feeding schedule per day for a bull of 300 kg body weight, 500 gm gain per day

Feed	Quantity	DM	TDN	CP
	------------------kg-----------------------			
Concentrate mixture	3	2.7	1.755	0.432
Green fodder	10	2	1.1	0.13
Straw	2.5	2.25	0.99	0.0675
Total(kg)		6.95	3.84	0.629
Required(g)		6.90	3.79	617
Balance (g)		+ 5	+ 5	+ 12
In the absence of sufficient quantity of green fodder for every 10 kg of green fodder 1.0 kg of concentrate may be included and 1.0 kg of dry fodder can be fed. It is strongly recommended to feed green fodder with legumes				

Table 8. Example of feeding schedule for a adult bull of 700 kg body weight) under practical conditions

Item	Quantity(kg)	DM (kg)	CP (g)	TDN (kg)
Green fodder	20	4	280	2.20
Dry fodder	7	6.3	189	2.83
Concentrate mixture	1.8	1.62	259	1.05
Total	-	11.92	728	6.08
Required		14	663	5.82
Balance		- 2.08	+ 65	+ 0.26
To balance DM, if increase the feed, CP and TDN will further increase				
CP and TDN coming from fodder are not fully digested as compared to concentrate mixture, hence under more fodder based diets, negative effects of higher CP and TDN intake is less. Reduce concentrate mixture to 1.50 kg instead of 1.80 kg, it will meet CP and TDN exactly, dry fodder can be given ad lib to meet dry matter.				
Validate the feeding schedule in few bulls and record the performance, make minor adjustments in consultation with a Nutritionist.				

Conclusion

Feeding of bull is important for creating next generation calf. Nutrient requirements for production of semen alone is inappreciable compared with requirement for maintenance or growth. Hence, young bull should be maintained for it's normal growth and maintenance and mature bull should be fed for its maintenance and activity. Excess feeding affects reproductive efficiency; particularly protein should not be fed in excess. Phase feeding as per the physiological condition should be followed for herd bull. The bull maintained for semen collection should not be exploited for more service and care should be taken to avoid over or under nutrition. Quality micronutrient supplementation improves semen quality.

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IMPROVEMENT OF FERTILITY IN DAIRY ANIMALS THROUGH REPRODUCTIVE TECHNOLOGY

A. Arangasamy, J. Ghosh, S. Selvaraju, B. Krishnappa, D T Pal and C G David

ICAR- National Institute of Animal Nutrition and Physiology, Bangalore 560 030
E mail: arangasamyars@gmail.com

Several reproductive biotechnology's tools are routinely used to shorten generational intervals and to propagate superior genetic material among breeding animal populations. Among the developed technologies over the past 5-6 decades, artificial insemination (AI), Oestrus synchronization, manipulation of fertilization *in vitro* (IVF), embryo transfer (ET), transgenic animal production and cloning are the familiar and well established techniques. Recently other technology i.e spermatozoa sexing/sorting is also becoming popular in the world. In this chapter, the most applied reproductive technologies are discussed for their roles in the improvement of livestock production.

Artificial insemination (AI)

Artificial insemination (AI) is the most widely used and accepted technique ever devised for the genetic improvement of farm animal species including buffaloes. It ensures the introduction of superior quality male germ plasm (sperm) to the female tract for fertilization to obtain offspring with higher production potential. Success and failure of AI influenced by various factors pertaining to male fertility, semen handling and storage, insemination technique, skill of inseminator, proper time of insemination and infections in the female reproductive tract. The development of AI as the predominant breeding method, combined with extensive record-keeping and formulation of genetic models to estimate breeding values for production traits has resulted in large increases in milk yield among cattle and buffaloes. The overall coverage of AI in cattle is around 28 to 32 %, and the conception rate is 32 to 35% respectively. However, AI in buffalo is still less popular for a technology among the farmers. Cattle and buffaloes showing oestrus in the morning should be inseminated on the same-day evening and those showing symptoms in evening should be inseminated on next-day morning. There should be synchronization between onset of oestrus and time of artificial insemination as ovulation occurs by about 12 to 14h after the end of the estrus. The life-span of spermatozoa is approximately 30 to 48h, and ovulated eggs remain alive for 12 to 18h. The insemination should be carried out keeping these points in mind to have successful fertilization. A minimum of 10 million live sperm cells/ insemination is required for successful fertilization. The frozen sperm cells are more fragile with shorter lifespan compared to liquid or fresh semen. Second insemination is needed, if delayed ovulation is expected or to get more success/ conception rate.

Oestrus synchronization

Estrus synchronization is the process, in which more female animals are brought to the heat state using hormonal interventions. Normally, the hormonal induced animals will have pre-ovulatory follicular activity with higher probability of estrus detection and accurate prediction of time for insemination. These approaches lead to increase conception rate than the normal methods of estrus detection and conception. Synchronization of estrus in cows and buffaloes is possible by either shortening (injection with luteolytic drug (prostaglandin) or extending (Injection/ supplementation of progesterone hormone) the length of the estrus cycle. Prostaglandin F_2 alpha can be given as single dose treatment or double dose treatment 10 to 14 days apart.

Embryo transfer technology (ETT)

Embryo transfer is defined as a process, in which the fertilized embryo is collected from a (superior) donor female and then transferred into a suitable recipient female and complete its development and finally normal parturition/delivery will happen. The second most commonly used biotechnology tool after artificial insemination followed by estrus synchronization. Through this technique, genetically superior female produces more offspring's than she could produce by natural reproduction in the normal process. The success rate is well recorded in various species of domestic animals, including cows, horses, goats, and sheep. The various necessaries pre conditions required for embryo transfer technology are namely, Selection and preparation of donors, Collection of embryos, Handling, evaluation, and storage of embryo, Selection and preparation of recipients and Practical embryo transfer. The major gains from the ETT are free movement of material worldwide and reduce the risk of transmitting certain specific diseases, provided the condition that embryos are free from contamination. The technology has its own limitation like the variability of the ovarian response to the superovulatory gonadotrophin treatment used so far. Another matter of concern with the manipulation of ovulation is the asynchrony between time of AI and occurrence of ovulation, and the decreased sperm transport registered after a superovulation treatment, both of which lead to low fertilization rates in cattle.

In vitro embryo production (IVP)

Methods for *in vitro* embryo production consists of three important steps, *in vitro* maturation (IVM), fertilization (IVF) and culture (IVC). This approaches also proved well with the birth of innumerable calves worldwide in cattle. The outcome of the success rate depend on oocyte maturation media conditions and type of oocyte used for maturation i.e either oocyte collected from slaughter house origin or ovum pick up methods. Again low oocyte retrieval/ yields per ovary are other issues for the success of IVP. The efficiency of IVP is low in Buffaloes than Cattle.

Cloning

Production of genetically identical individual from donor cells is called cloning. It involves the creation of individual or an animal that derives its genes from a single other individual. Nuclear transfer or Embryo splitting is increases the chances of developing embryo into two or more number soon after fertilization of the egg preferably it is performed at the 6-to 8-cell stage. Cloning technology has the potential to maximize the superior quality genetic resources in any geographical regions. Through cloning technology, ICAR-NDRI, and ICAR-CIRB brought glory to India by the successful production of Buffaloes cloning.

Transgenesis

Transgenic animals are genetically modified animal/individual and contain a foreign gene from a different species. Normally, it is done by molecular manipulations of endogenous genomic DNA gene or transplantation. This type of animal is used for breeding or biomedicine values.

Production of desired sex offspring

Sex pre-selection is an important aspect in the livestock enterprise to meet the demand for meat and animal products. Spermatozoa sexing and sex skewing through maternal diet manipulation facilitate to choose choosing the offspring of desired sex and minimizes culling. Several techniques such as swim up, gradient centrifugation, flow cytometry, lumisort, Raman's spectroscopy and immunogenic spermatozoa sexing are developed. Out of all these techniques available to sort X- and Y- spermatozoa, fluorescence activated cell sorter (FACS) is the most successful and commercially available technique, which employs sorting of spermatozoa based on DNA content. Despite its effectiveness, there are disadvantages with respect to cost, trained personnel needed, sperm damage, low conception rate etc. Other alternate approaches that might have potential significance could be identification of sex-specific membrane marker proteins for immunological method of sorting or by modulating the maternal diet. Maternal condition around conception has influence on offspring sex ratio. Maternal diet can be modified around conception for sex pre-selection through supplementation of selective minerals i.e Ca and Mg, K and Na, high fat or protein diet, and in vitro embryo production systems (glucose enriched media). Milieu of the female reproductive tract could be modulated by diet that in turn might selectively favour X- or Y- spermatozoa to fertilize the ovum. Development of potential and economically affordable alternate methods for sex predetermination at spermatozoa or at maternal nutrition levels are warranted in the livestock breeding industry.

Incidence of reproductive disorders

Among the many types of illness occurred in dairy cattle, reproductive disorder has major impact on the economy of milk production and livelihood of marginal farmers. The survey and findings related to the occurrence of reproductive issue in dairy cows, and heifers will have merit and alarm the animal owners and veterinarian to solve the problem in a timely manner. This present study was under taken to know the reproductive issues in some selected villages of Dodballapura regions (Hadonahalli, S. Nagenahalli, Ragihalli, Palpaldinne, Timogenahalli and Laxmidevipura villages of Karnataka state) under ICAR sponsored farmer’s first project. A total of two hundred and fifty eight (258) animals were examined during the period June 2017 to October 2019. Among the 258 animals, one hundred and sixty five (165) animals were brought for reproductive check up. Thirty five (35) animals were checked for pregnancy verifications and remaining one hundred thirty (130) animals were found to have reproductive problems i.e repeat breeder 49/130, anestrus 26/130, under developed genitalia 47/130, endometritis and abortion 7/130, cystic ovary condition Repeated Expression 1/138. The incidence of occurrence was higher for repeat breeder 37.69 %, followed by under developed genitalia 36.15 %, anestrus 20 %, endometritis and abortion 5.38 % and cystic ovary condition Repeated Expression 0.77 %, respectively. The remaining ninety three (93) miscellaneous cases were also diagnosed and treated for other ailments such as mastitis, skin lesions, blood protozoan diseases, deworming for worm loads, conjunctivitis, anorexia and weakness, fever, blood in stool, milk fever, respiratory lesions and insect bite.

Strategies to improve reproductive efficiency

The above-mentioned data on reproductive disorders could be useful in taking up the nutritional and physiological interventions to enhance the fertility in dairy animals. We have followed a group of treatments to overcome the above said major reproductive issues. The rectal examination was carried out in all animals, deworming doses (Fenbendazole 1.5 gm Bolus) was given followed by parenteral (i/m) administration of 10 ml each of A,D3,E and Tonaphosphan (AD3E: A 2,50000 IU, D 25000 IU, E 100 IU: Tonaphosphan: Sodium salt of 4-dimethylamino-2-methlphenyl-phoshinic acid 0.2 g/ml) on day 1 to all types of cases and for under developed genitalia cases, mineral mixture (ICAR-NIANP formulation) powders were administered orally @ 100 gm/day/cow for 30 to 90 days along with normal feeding pattern of farmer choices. In addition to the above treatment, Prajana capsules were given to the anestrus animals. For repeat breeding cows, advised for intra uterine washing & rest (if the animal not conceived even in 3 or 4 AI), and subsequent estrus AI along with injection of Receptal 1ml on the day of AI. With the above treatment majority of the repeat breeder and Anestrus cows responded well and conceived within two months of period. This method of approaches like deworming, mineral mixture, vitamins administration has a role in regularizing the balance of metabolomics and supported the steroidal hormone production and maintenance of conception in heifer/cows. Therefore, this method of nutritional and physiological interventions may be taken by the field veterinary officers to enhance the fertility in Heifer cows and to help dairy farmers to get the maximum benefit.

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SEMEN QUALITY AND MALE FERTILITY IN DAIRY ANIMALS

S. Selvaraju, S.S. Archana, D. Swathi, L. Ramya, B. Krishnappa, B.K. Binsila and A. Arangasamy

ICAR-National Institute of Animal Nutrition and Physiology, Bangalore-560030

selvarajuars@gmail.com

Artificial insemination (AI) is the first greatest assisted reproductive biotechnological tool successfully used for improving reproductive efficiency and disseminating superior germplasm in farm animals. It has an enormous impact on productivity in many species, particularly in dairy cattle across many countries. Though AI using frozen semen emerged 50 years back, fertility rate with AI is less and unpredictable. The major problem in AI appears to be the inaccurate semen analysis before freezing and as well as in post-thaw semen. The problem is also compounded due to the variation in fertility rate during natural service and insemination after semen processing. The use of sub-fertile or infertile semen can have devastating consequences in the breeding industry. Hence, efficient semen evaluation methods are needed to predict fertility potential of a bull with high reproductive efficiency and thus productivity.

Sperm motility and kinematics

Spermatozoa motility is commonly used to evaluate the fertilizing capability of a semen sample. In addition to being a measure of spermatozoon viability, motility provides an indication that spermatozoa are able to navigate the barrier in the female reproductive tract that must be overcome to reach the oocyte. Sperm motility reflects the physiological status of bull spermatozoa after semen collection or cryopreservation and does not correlate well with bull fertility. Even under physiological conditions, expression of motility is not an entirely reliable parameter of sperm integrity and the poor motility does not always indicate cellular damage.

In order to provide in-depth analysis to motility, sperm kinematics are assessed using computer Assisted semen analyzer (CASA). The CASA provides various aspects of kinematics including straight-line velocity (VSL), curvilinear velocity (VCL), average path velocity (VAP), Amplitude of lateral Head displacement (ALH), Wobbling, etc. However, so far, the precise parameters that are predicting the fertility at filed level have not been established.

Plasma membrane integrity

Assessment of plasmalemma characteristics is an essential feature for predicting the fertilizing ability of sperm. Sperm plasmalemma integrity is essential for sperm metabolism, capacitation, ova binding and acrosome reaction. Various tests being done to evaluate sperm plasmalemma include permeability to stains and biochemical function. Sperm stains such as eosin/nigrosin (EN), have been used to evaluate whether the plasmalemma is physically damaged or not. However, functionally active membrane is required for metabolism, capacitation and acrosome reaction attachment and penetration of the oocyte. Sperm with functionally intact membrane also has progressive motility and intact acrosome. Sperm with functionally intact membrane also successfully penetrate zona-free hamster egg indicating fertilizing ability. This technique, being simple and inexpensive may prove useful in studies involving the functional status of sperm membrane, possibly predict the spermatozoa ability to fertilize and be used as a means of evaluating fertility in bulls.

Acrosome integrity

Evaluation of acrosomal status is very important, because it is directly correlated with the fertilizing capacity. Functionally intact acrosome is essential for penetration of sperm through cumulus cells and zona pellucida. The use of morphological stains to characterize acrosomal status along with vital stains to differentiate live vs. dead sperm cells has been reported for cattle and buffalo. Using a stain that will differentiate acrosomal status as well as living from nonliving cells makes it possible to distinguish true acrosome reacted sperm.

Assessment of sperm Subpopulation positive for sperm functional membrane and acrosome integrity

Sperm functional membrane integrity and acrosomal integrities are estimated in spermatozoa using hypo-osmotic swelling-Giemsa (HOS-G) test. HOS-G test evaluates the sperm subpopulation positive for both functional membrane integrity and acrosome integrity in a spermatozoon. In a hypoosmotic environment, the sperm with functionally intact plasma membrane swell causing hairpin bend in the tail. Subsequent staining of these semen samples with Giemsa stain reveals acrosomal integrity. To achieve fertilization, the spermatozoa have to travel within the female reproductive tract and reach the ovum at oviduct for which plasma membrane intactness is indispensable. Subsequently for penetration through zona pellucida, acrosome intactness is of paramount importance. Thus, these test asses the most vital sperm attributes such as functional membrane integrity and acrosomal integrity.

DNA integrity and distribution:

It has been proposed that the existence of subtle sperm abnormalities that are unrecognized by conventional semen analysis may explain reduced fertility in assisted reproductive technologies in males. Therefore, a greater understanding of the molecular basis of male fertility is essential for sperm egg interaction and embryo development. Sperm with abnormal DNA distribution has been associated with improper zygotic, embryonic and or fetal development. Most of the sperm evaluation methods concern primarily the viability and functional status of spermatozoa, which influence the fertilizing ability of the gamete. However, vital factors essential for the sperm to produce a healthy and viable offspring primarily depends on the genetic material content. Since sperm DNA is uniquely condensed and organized, any abnormality associated with DNA, chromatin packing, or the sperm nuclear matrix should be reflected by a change in sperm nuclear shape. The evaluation of sperm DNA distribution could be useful for assessing male fertility.

Routine analysis versus recent concept:

Knowledge of fertility in bulls is an objective of great importance for the production of bovine semen, which is achieved by good analysis of the semen, among other assessments. The routine semen analysis relies on assessing a number of parameters such as sperm concentration, motility and morphology for the prediction of fertility in the male. These tests provide the information about the status of spermatogenesis and cannot be used as reliable predictors of sperm fertilizing ability.

The ability to predict the fertility of semen with laboratory tests is limited due to the complexity of the spermatozoon and the fertilization process. Many laboratory assays that examine spermatozoon cellular attributes test only a single attribute. Testing a single attribute is unlikely to measure fertility since the spermatozoa must meet many requirements for successful fertilization. Right combination of laboratory assays should test not only the ability of the spermatozoa to reach the site of fertilization, but also the ability of the spermatozoa to fertilize the oocyte and activate successful embryonic development. The most reliable approach is to use a combination of tests to evaluate different sperm attributes, thereby increasing the accuracy of the estimate.

Mitochondrial membrane potential

In recent years, mitochondrial function has been focused to assess semen quality. Assessment of mitochondrial membrane potential can be considered as the most sensitive semen evaluation test. The mitochondrial membrane potential varies significantly between animals and between groups, and has a significant correlation with cleavage rate. The reduction in mitochondrial membrane potential defines an early stage of apoptosis preceding DNA fragmentation, ROS production and the late increase in membrane permeability. Hence, determination of mitochondrial membrane potential may be considered as an important parameter in buffalo semen analysis.

Evaluation of sperm nuclear DNA damage

Over the last decade, rapid advances in reproductive molecular biology have resulted in numerous techniques to assess sperm DNA integrity. The ability of these techniques to accurately estimate sperm DNA damage depends on many technical and biological aspects. Some of the currently available tests evaluate the integrity of sperm DNA, including terminal deoxynucleotidyl transferase-mediated deoxyuridine triphosphate nick end labeling (TUNEL), the sperm chromatin structure assay (SCSA), comet assay, in situ nick translation, and DNA breakage detection-fluorescent in situ hybridization assay (DBD-FISH).

Molecular analysis of sperm

Sperm carry many molecules including DNA, transcripts, proteins and metabolites. Such molecules can be used for selection of bulls for breeding program.

Genomic selection of bulls

Bulls are selected based on the breeding soundness evaluation comprises of phenotype and seminal characteristic evaluation. Currently, bulls are also selected based on genetic composition. Presence of particular single nucleotide polymorphisms (SNPs) may have significant advantage in-terms of fertility over other bulls. Such genetically selected bulls may have fertility advantage over contemporaries.

Sperm Transcript profile

Sperm also carry transcripts which are indicative of spermatogenesis as well as may influence fertilization and early embryonic development process. Profiling of sperm transcripts and analyzing them critically with respect to sperm fertilizing ability may help to select bulls for breeding program.

Seminal plasma proteins

Sub-optimal fertility in males is a concern in humans and animals. In sub-fertile males, the factors contributing to their sub-fertility are largely unknown. In these situation analyzing fertility regulating protein, if any is considered to be helpful to improve fertility. The presence or absence of the critical concentration of proteins in seminal plasma could potentially responsible for the effects of seminal plasma on sperm fertility. Low fertility seminal plasma contains anti-fertility factors that have a greater negative effect on high fertility spermatozoa than on low fertility spermatozoa. In bulls, heparin-binding proteins in seminal plasma have been correlated with fertility. Studies indicate that identification and manipulation of fertility regulating protein to regulate fertility is highly important in cattle industry.

Sperm membrane protein

The fertilization is a multifaceted phenomena, every single steps leading to fertilization represents a critical point which could alter semen fertility. Depending on the steps involved in the process of fertilization, many sperm components such as lipids, proteins, ions and nucleic acids have been proposed to vary in quantity or quality according to the male fertility status in many mammalian species. Since the proteins present on the sperm membrane take part during zona binding and penetration. Soluble and structural proteins have an important role in the spermatozoal metabolism and bull's fertility. A 30-kDa heparin-binding protein named fertility-associated antigen (FAA) was identified in sperm membranes of beef bulls with greater fertility potential. It was also suggested that the effects of the FAA can carry over to the next generation.

Semen metabolites

Sperm is highly metabolically active cells and metabolize wide range of substances and hence presence of particular metabolite is indicative of their quality. Assessment of all the metabolites including amino acids, lipids, carbohydrates, nucleotides and hormones in a semen may help to predict the sperm fertilizing ability.

Conclusion

Semen analysis is very difficult for many reasons, including the use of subjective techniques with no standards for comparison, lack of technical skills, problems with proficiency testing and a reluctance to change techniques. The progressive forward motility count may suffice, overcoming the need for live and dead staining, however the research also suggests that DNA integrity measurements (sperm nuclear morphology, DNA distribution, DNA fragmentation tests) and mitochondrial membrane potential constitute valuable markers in the assessment of male fertility. In future, molecular analysis semen (genomic testing, transcriptome profile and sperm membrane protein profile) may be of indispensable tests for selection of breeding bulls.

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FERTILITY MANAGEMENT IN BUFFALOES

J. Ghosh, K.V.H. Sastry and A. Arangasamy
ICAR-National Institute of Animal Nutrition and Physiology, Bangalore

E mail: jghosh68@gmail.com

Worldwide there are two types of buffaloes, the Swamp and River types. India, Pakistan, Bangladesh, Sri Lanka and other neighbouring countries have River type buffaloes whereas Swamp buffaloes are found in South East Asian countries such as Philippines and China. The 95% of the buffalo population exist in the Asian countries and play a prominent role in rural economy. They are most adopted animals to tropical climate and utilize low quality feed, fodders and agricultural by product to produce valuable products in the form of milk, meat and hide. In Asian countries they are valuable draught purpose animal and are used for ploughing field and pulling carts as a support system for agriculture. By nature they are docile as a result animal attendant and children ride on their back for fun while taking them to and from the pasture and during wallowing in the water bodies.

Buffalo milk contains higher fat than cow's milk and is popular as a valuable resource for mozzarella cheese. Indian Cara beef is soft because of early age slaughter and is highly demanded in Malasia, Egypt, U.A.E., Thailand, Yemen, Japan, Southi Arabia, Oman, Kuwait and Qatar. Young buffalo meat (veal) is considered healthy due to low cholesterol contents and highly demanded by other countries.

Targets for optimal reproduction

Buffaloes are stamped as animal with low reproductive efficiency although the available literature indicates otherwise. Under optimal managemental condition buffaloes can perform at par with the expected efficiency of reproduction. Well managed buffaloes have average age of first estrus, first conception and first calving at 406, 647 and 963 days, respectively (Hafez, 1955) which is as expected ideally from these animals. Therefore the onus should go to the managemental practices not to the animals. The only concern the buffaloes have is the problem of estrus expression. However; with proper record and attention this can be overcome easily. It is obvious that the lack of attention to the animals happens when farmers are busy in other prioritised agricultural activities. Ideally a buffalo female has to produce a calf in every one and half years considering 315 days gestation period. They should achieve the following goals for optimal reproduction (Table 1).

Table 1. Targets of a buffalo female to achieve the best reproductive efficiency

Sl No	Parameters	Duration
1	Onset of cycling activity (puberty)	18 month
2	Calving to first service interval (days)	65 (+5)
3	Calving to conception interval (days)	85 (+10)
4	First service to conception (days)	20 (+5)
5	Overall pregnancy rate (%)	58 (-5)
6	First service pregnancy rates (%)	60 (-10)
7	Overall reproductive efficiency (%)	46 (-11)
8	Buffalo cows served that conceived (%)	95 (-5)

Nutritional requirement

The requirement of macro (energy and protein) and micro (minerals and vitamins) nutrients and its consequences of deficiency is not species specific. Both the macro (energy and protein) and micro nutrient (minerals and vitamins) impact reproduction in buffaloes similar to the way it does for the other animal species. The accepted fact for all the species is that both the deficiency and excess of energy and proteins feedings are deleterious for reproduction. Micronutrients toxicity is rare but the deficiency causes impairment of health and reproduction. Feeding management of buffaloes from the antenatal, prenatal, postnatal, puberty, during cycle and pregnancy is very important. The common concept of nutrition is that animals are to be fed as per the requirement keeping in view the growth and production. High energy rations improve average daily weight gain and consequently reduce the age at puberty. The buffalo heifers fed with high 5.56 MFU/d vs. low 4.42 MFU/d energy diets achieve average daily weight gain (ADG) of 562 vs. 465 g/day. Buffalo heifers that show a daily gain of 631 g per day reaches puberty at 598 days, while a daily gain of 441 g per day postpones puberty to 658 days. Generally, a growth rate of 500 – 600 g/d between 100 and 300 kg body weight is considered optimum for Indian buffalo heifers. Underfeeding that reduces growth rates during the rearing phase to 50% of the animal’s potential, delays puberty significantly. To attain 450 – 500g daily weight gain buffaloes have to be fed with a concentrate mixture containing 20% CP and 63% TDN. Therefore they may be fed @ 1.5, 2.0, 2.5 and 3.0 kg per head per day at 100, 150, 200 and 250 kg body weight or above along with 10 kg green fodder and *ad libitum* straw. When green fodder is not available, additional 1 kg concentrate mixture should be fed as replacement of 10 kg green fodder. For faster growth rate additional 1 kg concentrate may be fed daily.

The pregnant cow in lactation, need milking rest for a certain period to allow reserve build up and meet the need of the forthcoming events of parturition. A dry period of 60 – 75 days is generally advised. The energy stored during this period can be mobilized to meet the deficit in early lactation. During the rest period a good quality green fodder has to be fed. In addition 2–3kg concentrate per day is recommended for reserve building. At least 40% of the total dry matter (DM) requirement (1% of cow's body weight) should be met through good quality green fodders and the mineral requirement should be met through additional inorganic/organic salt supplementation. To ensure excess bioavailability organic mineral is better as it follows amino acid pathways of absorption. A shift from traditional dry buffalo diet (more fiber) to the early lactation diets (high in energy, protein, less fiber) is essential such diets are called transitional diets. Transitional diets should be fed for at least 3 wk before parturition, so that rumen microbes gradually get adapted to high-energy diets. The transitional dry buffalo diets should be formulated to minimize the incidence of metabolic disorders during lactation.

Physical body condition and reproduction

Physical condition of the body indirectly determines the success of reproduction. Any imbalance in the physiology affects reproduction as it is the most sensitive function of the body system. Reproduction is the luxury of the body system therefore is sensitive to anything that disturbs the upstream body functions. Both thin and fat animals are not good for reproduction (Table 2)

A general indicator of health condition can be assessed by the body condition scoring. Researchers found a good correlation between the body condition scoring and the several indicators of reproduction. It has been found that to achieve a body condition score of 3.5 in a 1 to 5 scale, during the late pregnancy period. To achieve this goal a proper feeding strategies has to be adopted to achieve this goal. It has been observed that buffaloes that score less than 3.0 during early lactation will have lower fertility.

Table 2. Reproductive problems associated with thin or fat body condition

Thin animals	**Fat animals**
1. Anestrus	1. Physical inability to move
2. Conception failure	2. Increased incidence of dystocia
3. Increased calving interval	3. Anoestrus
4. Irregular and delayed estrus	4. Conception failure
5. Decreased calf vigor	5. Increased susceptibility to reproductive tract infection

In buffaloes BCS range 3.5-3.99 showed early resumption of ovarian activity and estrus, less number of services per conception and first service conception rate with increased breeding efficiency compared to less or more body condition scores in post partum animals (Anitha *et al*., 2010). Therefore, the feeding strategies should target achieving the 3.5 to 4 body condition score in buffaloes for good reproductive performances (Figure 1).

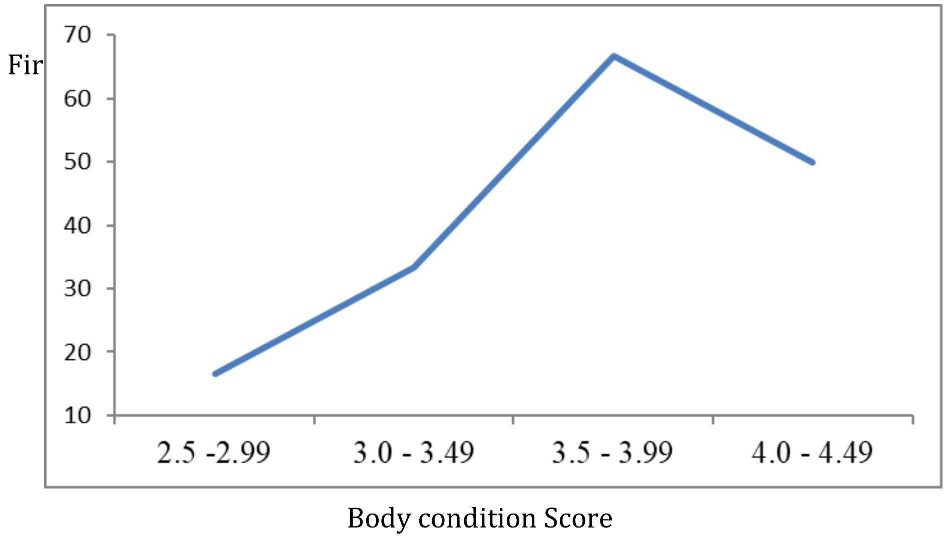

Figure 1: Relationship of body condition score and the first service conception rate in Murrah buffaloes. Data for the plot is derived from Anitha *et al* (2010)

Control of oestrous cycle is the best way to tackle estrus expression related issues

At puberty buffalo females come to oestrus by about 21 days interval (range between 19 to 14 days). The whole 21 days cycle is divided broadly into follicular and luteal phases. The short 2- 3 days proestrous and estrus period when behavioural signs are observed falls in the follicular phases of the cycle whereas the rest long 17-19 days period comprising of met-estrus, early diestrus and late diestrus falls in the luteal phases of the cycle. Buffaloes being mono ovulator a single follicle ovulate at estrus which is developed during the follicular phase. The pre-ovulatory follicle secretes estrogens that bring about the behavioural changes in the females the desire to receive the males and brings about the lutenizing hormone (LH) surge. The size of the pre-ovulatory follicle in buffaloes is more than 10mm dia. They grow to mature and discharge oocyte (ovulate) at estrus effected by the changes brought about by the LH surge. The oocytes ovulated from the follicle in a cycle either gets fertilized and gives rise to embryo or go waste without fertilization and subsequent development. The remaining part of the follicles in the ovary transformed and develops into corpus luteum gradually over the progress of the cycle days. Corpus luteum a temporary endocrine organ develops by differentiation of follicular cells that secret progesterone. Progesterone blocks reappearance of the cycle and ovulationvia negative feedback mechanism. The follicles that grow to preovulatory sizes in presence of functional corpus luteum do not ovulate due to the block of progesterone to the preovulatory gonadotropin (LH) surge. Meaning until the corpus luteum is functionally active does not allow another follicle to ovulate. If a well grown developing embryo is present in the uterus it initiates the process of maternal recognition of pregnancy to prevent the death of the CL. In absence of maternal recognition of pregnancy prostaglandin F2α is released from the uterine endometrium to cause demise of the functional CL and withdrawal of progesterone block that is essential for further growth of preovulatory follicles and subsequent ovulation. The entire concept of controlling the duration of estrous cycle in farm animal species including the buffaloes emerged from this understanding. Taking a control of the cycle is possible either by shortening or lingering the life of the CL. Several protocols popularly known as estrous synchronization methods are available as an out of different research and are available and adopted as per the need of the animals. These are accomplished by the use of different hormonal preparations (Table 3).

Some of these cycle and ovulation controlling protocols are very useful to overcome the problem of conception related to the issues of estrus detection in buffaloes. Synchronization of estrus and fixed time insemination is best suited protocols for buffaloes in this regard among the several protocols available in text book and research articles. User should understand it before practicing in the field. All the protocols use several hormonal treatments alone or in combinations. A prior knowledge on the function of each hormone and their doses is very important. In animals these hormones have no reported side effects not the residual effects that might affect the quality of milk. They accomplish the shortening or prolongation of cycle or induce the release of preovulatory LH. Even in our All India Coordinated research project such protocols are being used

Table 3. Commercial products used for artificial control of cycle in buffaloes

Sl No	Name of the product	Control functions	Dose and route of administration
1	Prostaglandins Lutalyse ® Estrumate ®	Demise of CL	5mL, intra muscular 2mL, intra muscular
2	Progesterone analogue/Progestins CIDR ®	Extends the luteal phase and life of follicle	Vaginal insert *
3	GnRH Receptal Cystrolrelin ® Factrel ® Fertagyl ®	Induce release of ovulatory LH to time ovulation	2.5mL im or iv 2mL, im or iv 2mL, im 2mL, im or iv

Natural breeding Vs artificial insemination

Success of conception by natural breeding is better compared to the artificial insemination in buffaloes. However, if properly stored semen is used for insemination following the ideal thawing protocols artificial insemination is equally good and convenient. The main point to ponder on buffalo is that sperms are more susceptible to cryo damage than cattle. It needs more research in this area for development of a semen extender that enables better protection to the buffalo sperms during cryo-storage and better post thaw motility after thawing. Maintenance of cold chain is must during storage of semen and during transport from one place to other. Negligence on the LN_2 supply and filling could be damaging more on the post thaw motility and conception rate. Also standard operating procedure for LN_2stored semen straw thawing has to be followed strictly. In addition inseminator must acquire right knowledge on the buffalo reproductive tract particularly the cervix, positioning of semen straw and AI gun, on the technique of proper AI in buffaloes. Role of veterinarian is very important to give faith on AI to the farmers.

General and reproductive tract health is important

Buffaloes are resistant to many diseases and parasites of cloven footed animals. However diseases that needs vaccination particularly the FMD has to be taken care. Bull stations have to be kept free of the transmissible diseases so the spread of infection is prevented to the cows. Hygiene during insemination is also important otherwise this will have serious consequences on reproduction and increase in repeat breeder cases. If the sterilization of insemination gun is not taken care properly this might be a source of another animal reproductive tract infection.

Conclusions

Increasing efficiency of reproduction is the key for success of any animal enterprises whether it is mass production or the production by the masses. Farmers in the costal belts prefer buffaloes compared to cattle this is simply because these animals are better suited for living in the water bodies, the climatic conditions and the environment available in that region. They can survive better than cattle in water logged areas and are resistant to many parasitic diseases. Most importantly they have the better skill of survival with the low quality roughages. They are normally docile and calm so are preferred animals in rural India in spite of the requirement of many scientific and managemental interventions. They contribute about 45% of meat and 55% milk in India so importance is immense. Therefore a lot has to be cheered about this animal keeping in view the Indian scenario.

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DIFFERENT STRATEGIES TO SUSTAIN DAIRY CATTLE PRODUCTION IN THE CHANGING CLIMATE SCENARIO

V.Sejian, C. Devaraj, M.V.Silpa[1], E. Vadhana, C.G. Shashank, V.B. Awachat and R. Bhatta
ICAR-National Institute of Animal Nutrition and Physiology, Bangalore
[1]Institute of Animal Breeding and Genetics, Justus-Liebig-Universität Gießen, Gießen, Germany
E-mail: drsejian@gmail.com

While climate change is a global phenomenon, its negative impacts are felt more severely by poor people in developing countries, who rely heavily on the natural resource for their livelihoods. Rural poor communities depend a lot on agriculture and livestock for their survival. Further, animal agriculture is amongst the most climate-sensitive economic sectors in India. Dairy farming provides employment, sustainable income and social security to a large population across the globe. Climate change and global warming cause great threat to entire livestock population across the world. Impact of climatic extremes and seasonal fluctuations on herbage quality and quantity are considered as imperative source of influence on the well-being of livestock in extensive production systems. This can result in impairing reproduction and production efficiency of grazing animals. The extreme heat during summer months negatively impacts grazing animals, and is capable of inducing nutritional imbalances. In arid and semi-arid areas, livestock are often considered to be one of the most important means of food and economic security for poor and marginal farmers. Inadequate and low quality feed is a major factor in under-production of animals in arid and semi-arid tropical regions. Under-nutrition in livestock can occur in late spring and summer due to increased energy output for thermoregulation and concurrent reduction in energy intake. While understanding the science of animal nutrition continues to expand and develop, most of the world's livestock, particularly, small ruminants in pastoral and extensive mixed systems in many developing countries, suffer from permanent or seasonal nutritional stress. This chapter is an attempt to collate information on different strategies to improve livestock production under the changing climate scenario.

Climate change impact on livestock production

The climate change has great influence on the livestock industries affecting production, reproduction, animal health, input costs, product prices, and natural resources management. Climatic factors, such as ambient temperature, relative humidity, solar radiation, and wind speed, influences dairy animals, especially cattle. The direct effect of climate change on cattle is thermal stress while the indirect effect being the low pasture availability and water scarcity and the increased incidence of pest and diseases. Heat stress and nutritional stress are the major factors that severely affect the reproductive performance of dairy cattle under the changing climate. Increased ambient temperature leads to heat stress and decline in fodder and pasture availability due to increased temperature and decreased rainfall have detrimental effect on reproduction in dairy cattle. Effect of heat stress includes reduced dry matter intake, increased water intake, Increase sweating and panting to maintain core body temperature, Energy is shifted from milk production to maintenance, increased mortality and morbidity, increased rectal temperature and respiratory rate. Table 1 describes changes in animal physiology due to heat stress in dairy cows.

Climate change has the potential to impact the quantity and reliability of forage production, quality of forage, water demand for cultivation of forage crops as well as large-scale rangeland vegetation patterns. The most visible effect of climate change will be on the primary productivity of forage crops and rangelands. Most of the impacts of climate change on livestock production are mediated through non availability of feed resources as well as affecting the quality of existing feed resources. Climate change impacts livestock production by affecting feed crops production and grazing systems. Grasslands cover about 70% of the world's agricultural area and they face a wide range of challenges from climate change including the effects of elevated atmospheric carbon dioxide, higher temperatures, and changes in precipitation regime and increasing concentrations of ground level ozone. These changes can adversely affect productivity, species composition and quality, with potential impacts not only on forage production but also on other ecological roles of grasslands.

Table 1. Changes in animal physiology and other parameters due to heat stress in dairy cows

Decreases in:	Increases in:
Dry matter intake	Weight loss
Rate of feed passage	Somatic cell counts
Blood flow to organs	Clinical mastitis
Rumen buffering capacity	Respiration rates
Milk yield and quality	Rectal temperature
Reproductive efficiency	Water intake
Body condition score	Sweating
Heifer growth	Salivation
Immune function	Health care costs

Production efficiency, profitability, and sustainability of commercial livestock production are depended on reproductive efficiency. In summer, heat stress may reduce the fertility of dairy cows by poor expression of estrus due to a decreased estradiol secretion from a dominant follicle developed in a low luteinizing hormone environment. Productivity of dairy cows is also negatively affected due to long inter-calving intervals, which occur due to low conception rate (CR), long sexual inactivity after parturition and poor expression of oestrus. Level of nutrition plays an important role in reproduction. Decreased levels of the antioxidant vitamins are associated with poor fertility and production levels in ruminants. Poor reproductive efficiency is observed in lactating dairy cows because of low fertility and low rates of estrus detection. The relative importance of reproductive management in the efficiency of dairy production vary according to the environment, genotypes, scale of inputs and outputs, managerial skills of the farmers and economic as well as sociological considerations. Disease outbreaks as a result of climate change have adverse effects on reproductive performance of dairy cattle. Immune responsiveness of domestic animals is reduced due to heat stress. Veterinary assistance should be given if the conditions such as abnormal discharges persisting more than 15 days after calving, no heat observed by 60 days after calving, absence of conception after more than three repeated services, abnormal discharges during heat like flaky mucus or pus, calving difficulties, retained placenta or other reproductive disorders occurs in heifers or cows.

Strategies to sustain livestock production in the changing climate scenario

This section discusses in detail the various strategies such as (i) shelter management; (ii) nutritional interventions; (iii) animal genetics and breeding and (iv) animal health management. Fig.1 describes all these strategies in detail.

Management strategies to improve dairy production in the changing climate

Animal housing is one of the approaches to alleviate the impacts of climate change on cattle. Shade reduces the severity of heat stress in animals that are being exposed to sun. It is an effective method to protect the animals from radiant heat load and helps to cool the animals. Shades can be made artificial or natural. Aluminum or galvanized steel roofs are artificial shades while the roofs made out of straw are of natural means. Provision of trees and other vegetative covers over the surrounding area will reduce the effect of radiative heat load on the cattle. Roofing materials should always be a bad conductor of heat and the best housing will have roofs painted in white so as to reflect the radiation of sun. Physical protection with artificial or natural shade presently offers the most immediate and cost-effective approach for enhancing reproductive efficiency of animals. Evaporative cooling also can be effective. Various shade management systems have been evaluated extensively and generally result in improved feed intake and productivity. The orientation of the shed should be in north-south direction in the northern hemisphere so that the direct incidence of solar radiation into the shed is avoided. For effective heat dissipation in cattle, there should be free flow of air inside the shed, this can be done by increasing the ventilation by means such as keeping half side wall i.e., open housing system, use of fan, increasing the height of the building etc. Shade alone will reduce a cow’s respiration rate by 30%, and adding sprinklers will reduce the respiration rate by 67%. Both methods of cooling will also lower rectal temperatures. Use of shade plus fans and sprinklers has an additive effect. Use of fans is important, especially in confined structures, because fans help to move warm air from cows’ bodies.

One of the best practices to reduce heat stress is to provide adequate fresh, cool, clean drinking water. Other methods of cooling include shade, commercial coolers, tunnel ventilation; shower/fanning stations, fans, cooling ponds and center pivots. Cows generate approximately 20% of their gross energy as body heat, which is released to the surrounding air, making them feel hot, especially under heat stress conditions. Fans remove this body heat via convection, thereby cooling down the surface of the animal. Sprinklers are used to soak the cow's hair coat to the skin with water, allowing the loss of body heat via conduction. Fans plus sprinklers allow for conduction and evaporative cooling, as the fans help to vaporize the water that has been warmed by the release of body heat. Marked relief was observed in cows by the use of fans plus sprinklers, which reduced respiration by 50% to 50 breaths per minute.

Water and air movement becomes the major agents by which the microenvironment inside the barn is cooled and evaporative cooling by the animals is augmented. Enhancing heat loss with the help of sprinklers/misters/foggers along with fans and installation of air conditioners in extreme hot climates are the main strategies for mitigating the heat stress. Sprinkling animal in the morning is more effective than sprinkling in the afternoon. Certainly it is recommended to start cooling strategies prior to animal showing signs of heat stress (panting). Sprinkling of pen surfaces may be as much or more beneficial than sprinkling the animal. Cooling the surface would appear to provide a heat sink for animal to dissipate body heat, thus allowing animal to better adapt to environmental conditions vs adapting to being wetted. In handling studies, moving animal through working facilities requires an expenditure of energy causing an elevation of average body temperature between 0.5 and 1.0 °C (.9 and 1.8 °F), depending on the ambient conditions. So during hot days minimal handling of animal is recommended for promoting animal comfort. Some farmers even acclimatize their animals intentionally by exposing them to artificial thermal conditions in order to prepare themselves before the season and thus preventing stress losses. Reducing the stocking density during hot weather will help the animals in dissipating the body heat more efficiently and during cold conditions the stocking density can be increased. And also the cattle should be provided bedding and warmth to protect them from extreme cold weather.

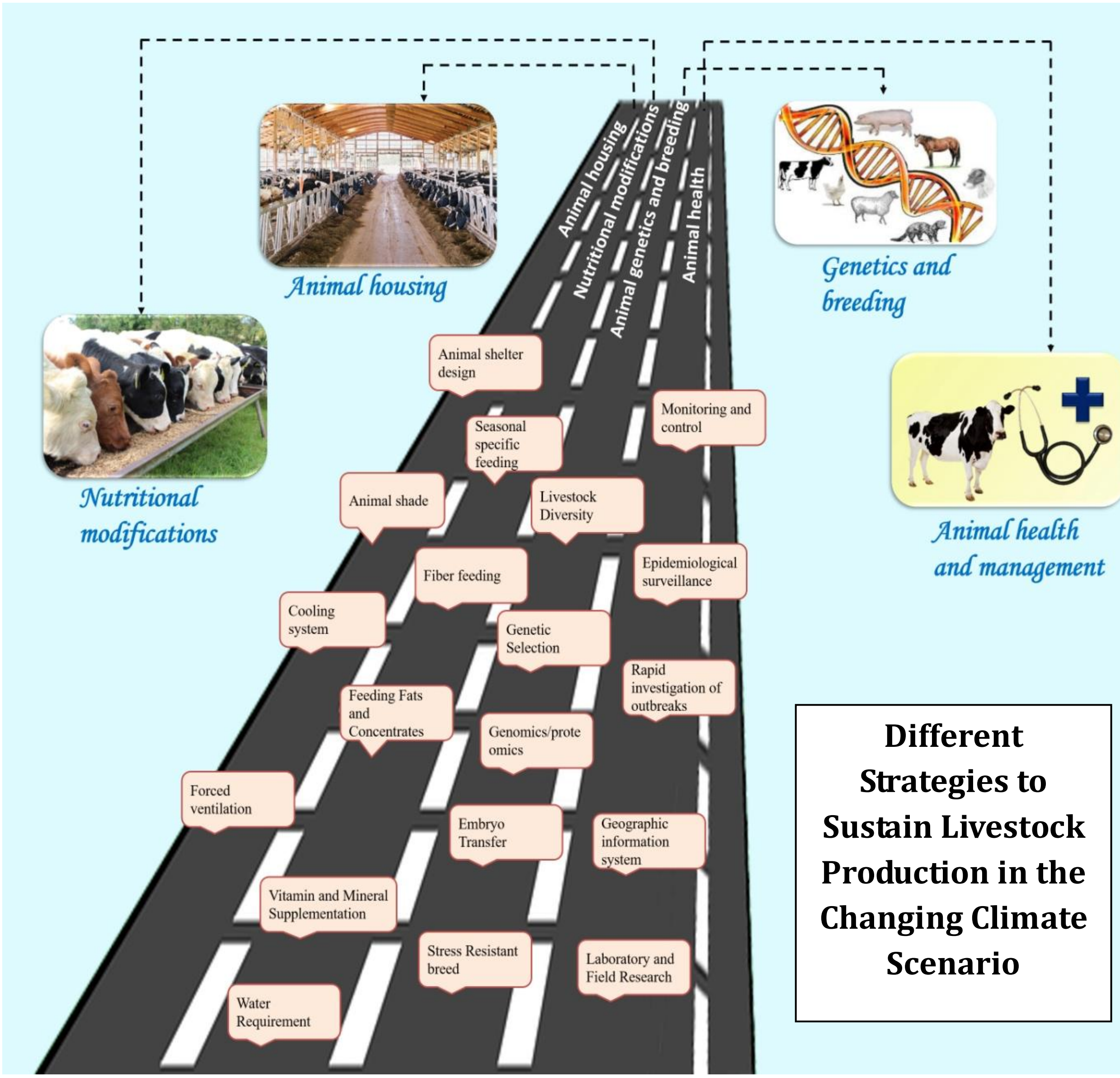

Fig. 1 Strategies to sustain livestock production in the changing climate scenario

Nutritional strategies to manage dairy cattle under changing climate

Water, the most important nutrient for the dairy cow, must be readily available, clean and cool to encourage consumption. Cows will drink 50% more water when the ambient temperature is 80°F compared with 40°F, so instead of consuming the average 30 gallons per day, their intake may increase to 45 gallons or more. The water consumed is used to cool cows' bodies via respired moisture and sweating as discussed above. The chilling of drinking water to 50°F alleviates heat stress as evidenced by decreased respiration and rectal temperature, resulting in increased feed intake, rumen motility and milk yield. It is important to provide at least 2 inches of trough space per animal in confinement barns to maximize access to water. It should be noted that excessive lowering of rumen temperatures by offering very cold water may suppress microbial activity and slow the fermentation process, subsequently requiring more feed energy and heat production, which is very inefficient.

During hot dry summer there is decrease in dietary feed intake which is responsible for the reduced productivity. In this situation the efficient practical approaches like frequent feeding, improved forage quality, use of palatable feeds, good nutrition balance and greater nutrient density are required. Because there is greater heat production associated with metabolism of acetate compared with propionate, there is a logical rationale for the practice of feeding low fiber rations during hot weather. Changes in diet are needed during hot weather to maintain nutrient intake in order to maintain homeostasis. Optimizing ruminally undegraded protein improves milk yield in hot climates. The recommended level of crude protein in the diet should not exceed 18 % and the level of rumen degradable protein should not exceed 61 % of crude protein. The Mineral losses via sweating especially potassium and changes in blood acid-base chemistry resulting from hyperventilation reduce blood bicarbonate and blood buffering capacity and increase urinary excretion of electrolytes and as a result the supplementation of electrolytes are essential. Of the three main rumen-produced volatile fatty acids, propionate is the one primarily converted into glucose by the liver. Highly fermentable starches such as grains increase rumen propionate production, and although propionate is the primary glucose precursor, feeding additional grains can be risky as heat stressed cows are already susceptible to rumen acidosis. Heat production is lower when the cattle are fed with feed ingredients such as concentrates and fats, whereas forages have a greater heat increment and in addition to that the feeding of high fibrous diets will lead to production of more acetate which has more heat of nutrient metabolism in comparison to propionate. Ruminant diets with grain and low fiber produce less heat stress for lactating cow because of their lower heat of digestion. However a good quality of roughages should be fed in order to prevent acidosis. Improved dietary energy density and the lower heat increment associated with the inclusion of dietary fat must be coupled with limitations to fat feeding to avoid ruminal and metabolic disorders. There are studies demonstrating that dietary fat can be added to the ration at up to 3–5% without any adverse effects to ruminal micro flora. Improved efficiency and lower heat increments should make fat especially beneficial during hot weather. Ruminally protected fats allow the inclusion of a substantial quantity of fat in the diet, which could lower heat increment significantly. Supplementation of saturated fatty acids at 1.5 or 3.0% of diet dry matter increases the milk yield, milk fat content and yield, and reduces the peak rectal temperatures in heat stressed cows. The feeding time also has great significance as the feeding behavior of the animal changes, studies state that feeding during the cooler hours of the day and also increasing the number of daily feeding proves beneficial against the heat stress. Increasing the feeding frequency will also help to minimize the diurnal fluctuations in ruminal metabolites, increase the feed utilization efficiency in the rumen and it further enhances the animal's ability to cop up with the heat load during the summer.

Addition of monenesin increases propionate production. In addition, monensin may assist in stabilizing rumen pH during stress situations. Propylene glycol is also typically fed in early lactation that may be an effective method of increasing propionate production during heat stress. In a study where heifers were supplemented with increasing amounts of chromium the insulin sensitivity increased, suggesting that chromium plays an essential role in glucose metabolism in ruminants. Because glucose use predominates during heat stress, chromium supplementation may improve thermal tolerance or production in heat-stressed animals. For instance, supplementing heat-stressed early lactation dairy cows with chromium reduced the degree of weight loss, improved milk production, reduced the concentration of plasma non esterified fatty acid (NEFA) and improved rebreeding rates. Feed additives like Niacin, Na bicarbonate buffer, antioxidants, fungal yeast culture, Lipoic acid and Thiazolidinediones supplementations are good practices for alleviating heat stress. So matotrophin treatment in cows is known to increase the milk yield up to 15 % in even severely heat-stressed dairy cows. In addition to all these *ad libitum* quantity of non-contaminated water should be provided as it is a crucial necessity for livestock survival and productivity. It is a well-established fact that during heat stresses the water requirement of the animal increases about 2 to 4 times. Water management strategies for both surface and ground water resources should be undertaken like interlinking of rivers, integrated water resource management, improved water harvesting techniques etc. at both local and national levels. Another major constraint in the tropics is the non-availability of the feed resources during the summer. This can be overcome by the use of non-conventional feed resources like castor bean meal, neem seed cake, tomato pulp, vegetable wastes, pineapple silage, azolla, areca sheath etc. Also the forage management practices like growing of hydroponic grasses, silage preparation, feeding of hay and growing of summer or drought tolerant varieties like Bahiagrass.

Nutritional tools, such as antioxidant feeding (Vit-A, selenium, zinc etc.) and ruminant specific live yeast can help. Studies have shown that addition of antioxidant in diets of cows is able to reduce stress and is a good strategy to prevent mastitis, optimize feed intake and reduce the negative impact of heat stress on milk production. Moreover, the use of antioxidant such as Vit-E, Vit-A, selenium and selenium enriched yeast help reducing the impact of heat stress on the oxidant balance, resulting in improved milk quality and cow health. A recent study in cattle showed that the supplementation of Vit-E help in reducing the heat stress and improves the antioxidant status and lowers the incidence of mastitis, metritis, and retention of placenta.

Body condition scoring as a simple nutritional tool to optimize livestock production

Condition scoring is a system of describing or classifying breeding animals by differences in relative body fatness. It is a subjective scoring system but provides a fairly reliable assessment of body composition. Body condition scoring is a simple but useful procedure, which can help producers making management decisions regarding the quality and quantity of feed needed to optimize performance. Under Indian farming condition, 5-point body condition scoring system similar to the one followed in United States is preferable. Body condition scoring provides a reasonable indicator of status of cows at different production phases, which allow to assess cow’s nutrition level and to decide when, and how to supplement the herds. It is desirable to have cows in 3 or 3.5 BCS at the time of mating to get higher calving rate and as well as more birth weight of calves per calving. It is therefore essential to have a simple and reliable indicator like BCS at hand, which allow to assess nutrition level of cows particularly in production systems where the availability of feed is not constant and to decide when and how to supplement the herd for getting maximum productivity.

Reproductive management of dairy cattle during stress condition

Estrus synchronization, embryo transfer, hormone assay, ultrasonic imaging are some of the modern reproductive technologies which has wide range of potential applications. Application of these modern technologies can play crucial role in reproductive management of dairy cattle under changing climate scenario. Estrus synchronization offers scope for better planning of breeding activities and wider use of AI. This can improve estrous detection rates. Treatment of prostaglandin F2αin early diestrus resulted in the greatest degree of estrus synchrony and in conjunction with estradiol decreased the interval to estrus and ovulation. Synchronization with prostaglandin F2αwas successful when cows were bred to a detected estrus, because rates of estrus detection increased and management of AI was more efficient than daily detection of estrus. Some of the management strategies for reducing the impact of heat stress include temperature and humidity control, mineral and vitamin supplements, embryo transfer, hormonal therapy. Effects of heat stress on fertility can be reduced, using shade, fans, air-conditioning and sprinkler systems to cool animals. Antioxidant supplementation can increase the incidences of estrus, increases the fertilization rate, increases the conception rate, and prevents the dystocia and other reproductive tract complications. Using of embryo transfer will bypass the harmful effects of heat stress on oocyte quality that limit embryonic development. Decreased plasma levels of LH and estradiol are in heat stressed cows is one of the main factors contributing to low fertility during the hot months of the year. Use of reproductive hormones to stimulate fertility is an alternative approach to improving summer fertility. Effective reproductive management of dairy cattle is essential for obtaining good production under the changing climate scenario.

Exploiting the genetic potential of local/indigenous breeds

In the face of changing climate scenario, efforts are needed to exploit the genetic potential of indigenous livestock breeds of different species. Productive traits need to be targeted to assess the performance of such indigenous breeds. After thorough assessment appropriate breeds needs to be developed which are able to survive to the local environmental conditions? With the advancement in molecular biotechnological tools, it is possible to identify and characterize genes responsible to adapt to drought and heat stress. Efforts are also equally needed to carry out several simulation studies involving programming various ranges of temperature and humidity in the climate controlled chambers. Such efforts can help to identify important biomarkers for climate change associated environmental stresses which can be used in Marker Assisted Selection (MAS) breeding to evolve suitable breed which has the ability to survive in different agro-ecological zones in India.

Improved health service

Increase in temperature and humidity due to climate change is strongly associated with emerging and re-emerging animal diseases by (i) increasing the diffusion of insects Culicoidesimicola) that are the main vectors of several arboviruses (e.g. bluetongue, and African sickness); (ii) increasing the survival of viruses from one year to the next; (iii) improving conditions for new insect vectors that are now limited by colder temperatures (Mellor and Wittmann, 2002; Gould et al., 2006). This will lead to production losses. Thus, improved diseases control strategies and health service at a big scale is required.

For prevention, monitoring and control of livestock diseases good data exchange mechanism are required at both state and national level. These should cover the distribution of animal diseases, ecological conditions including climate, and associated drugs and chemotherapeutants. In this contest, epidemiological surveillance is a critical component and it not only involves the early identification of emerging diseases and trends but also for resource planning and measuring the impact of control strategies. A global approach to epidemiological surveillance should be taken and should involve collaboration between professionals involved human, animal and environmental health. Such surveillance programmes are essential in allowing us to recognize and respond to emerging risk to climate change. We can also use the geographic information system (GIS) by which we can both monitor the level of stress and how our climate is changing and monitor the spread of diseases. We can use it to look for periods or heavy rainfall using a spatial analyst and illustrate it using GIS. This system tells us which pathogens will flourish, under their preferred condition. This tool can also help to pinpoint period of continually high minimum temperature. Likewise predictive modeling system can also be used to predict the probability of an outcome. It has potential to predict the probability of global climate change on ecological system and emerging hazards. Furthermore, laboratory and field research will also help in illuminating how climate changes influence pathogen characteristics, and models will help researchers and producers predict and plan for pathogen threats.

Adaptation strategies to sustain livestock production under changing climate

Adapting to climate change entails taking the right measures to reduce the negative effects of climate change or to exploit the positive impacts by making appropriate adjustments and changes. The highly adapted indigenous breeds identified by marker assisted selections can be used as an efficient tool for developing thermo-tolerant breeds through improved breeding programs. Promotion of such breeds can improve the production efficiency and may lead to less greenhouse gas emissions. Further, women hold rich knowledge and wide skills for maximizing the use of natural resources. Hence, occasional training and participatory research approach into the roles of women assists tackling of climate change in the rural areas. In addition, well-organized early warning systems avoid severe damages due to unexpected disasters by providing sufficient time to prepare effective response. Development of skilled disease surveillances supported with effective health services may effectively control the spread of the climate change related diseases in goat. Furthermore, improved water resource management should be developed to meet the water requirements for goat production in tropical regions. Cultivation of drought tolerant fodder varieties in extreme hot areas is an efficient adaptive strategy to ensure sufficient supply of feed during scarcity period. Finally, strengthening extension services and building awareness through capacity building programs helps the livestock keepers to improve their adaptive capacities against climate change. Adaptation strategies related to cold stress includes advanced cold tolerant breeding programs, migration in extreme winter and adoption of proper cold management practices. Hence, there is an urgent need to develop better policies and practices that ensure cost effective adaptive strategies to tackle climate change. Fig. 2 describes the different adaptation strategies to sustain livestock production in the changing climate scenario.

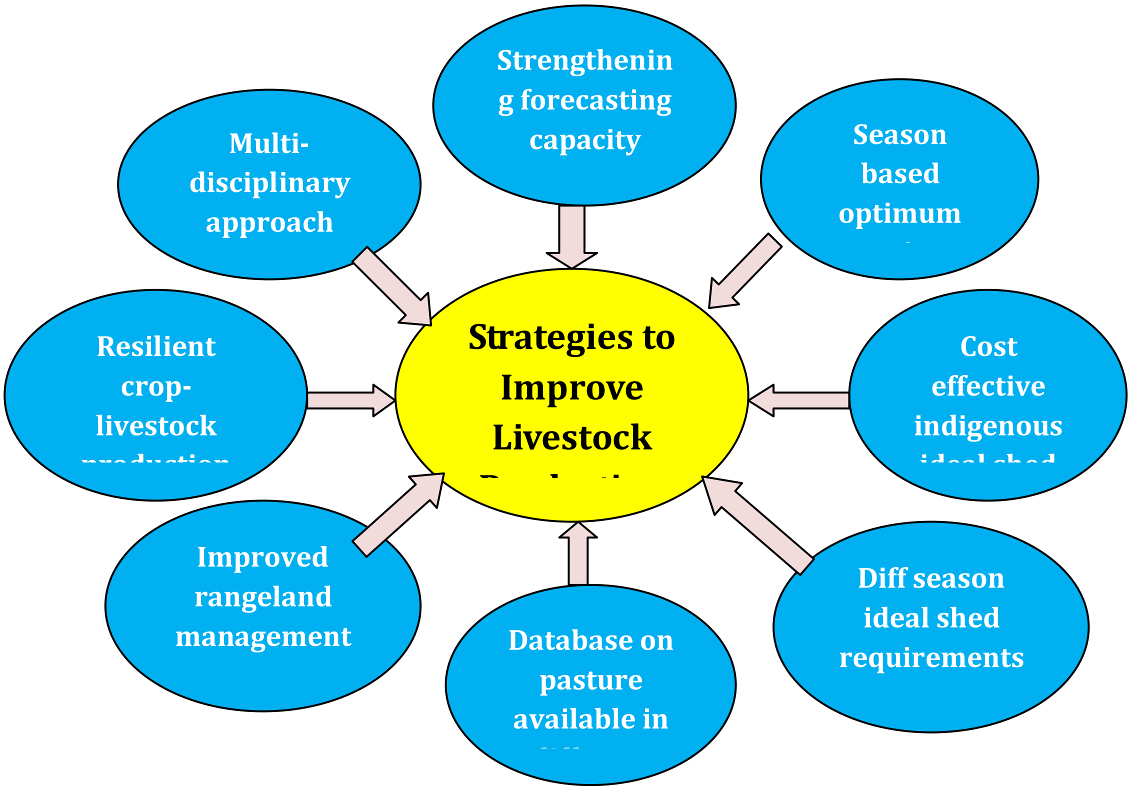

Fig. 2. Different adaptation strategies to improve livestock production in the changing climate scenario

Conclusion

Stress is continually imposed upon dairy cows to produce more and more milk. To maximize yield, it is imperative to keep cows as comfortable as possible and maintain feed intake for conversion into milk. Heat stress negatively affects cow comfort, dry matter intake and, subsequently, milk yield; thus, management strategies must be applied to counter hot/humid environmental conditions that can lead to mastitis, increased SCC and reduced milk quality. Control is based on provision of fresh, cool, clean drinking water, and increased energy density of rations and use of feed additives, as well as the use of cooling mechanisms including shade, fans, sprinklers, tunnel ventilation, commercial coolers and cooling ponds. Scientific research can help the livestock sector in the battle against climate change. Research must continue developing new techniques of cooling systems such as thermo-isolation, concentrating more than in the past on techniques requiring low energy expenditure. New indices that are more complete than THI to evaluate the climatic effects on each animal species must be developed and weather forecast reports must also be developed with these indices, to inform the farmers in advance. Above all to beat the climate change or in any case not to let the climate beat livestock systems, researchers must be very aware of technologies of water conservation.

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STRESS AND SHELTER MANAGEMENT OF DAIRY ANIMALS

Mukund A. Kataktalware, Priyanka Meena, Priyanka Patoliya, S. Praveen and G. Letha Devi[1]

ICAR-National Dairy Research Institute, Southern Regional Station, Bangalore

[1] ICAR-National Institute of Animal Nutrition and Physiology, Bangalore

Email: mtalware@gmail.com

As per the Sixth Assessment Report, 2021 of the Intergovernmental Panel on Climate Change global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation and the severity of wet and dry events. Rising global temperatures impair dairy cow productivity by reducing milk production, impairing reproductive success, and increasing morbidity and mortality (Dado-Senn *et al*., 2019). In the dairy industry, heat stress and its induced heat strain result in huge economic loss every year (Shu *et al*., 2021). In developing economies like ours, the dairy sector not only provides employment and income to rural households but also contributes significantly to all-encompassing growth. The impact of undiminished environmental stress could lead to decreased productivity, increased mortality and reduced profitability of dairy farms. Therefore, it is high time that necessary measures are adopted for the alleviation of environmental stress on dairy animals. Against this backdrop, the importance of animal shelter as one of the most adaptable and economical strategies is discussed herewith.

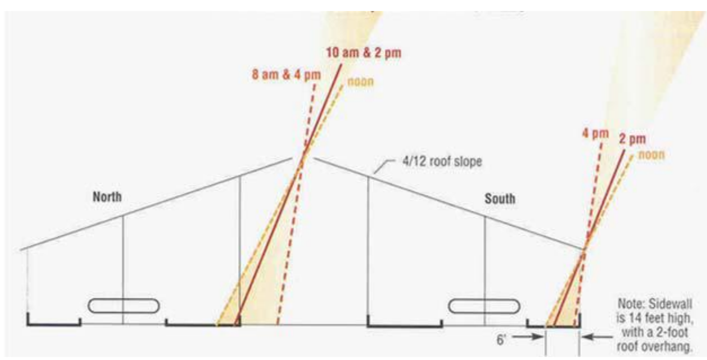
Heat stress

Thermoregulation is of importance for homeotherms to maintain homeothermy and homeostasis by keeping the balance between the production and loss of body heat (Kadzere*et al*., 2002). Heat production in dairy cows mainly comes from basal metabolism, rumen fermentation, nutrient absorption, growth, lactation, gestation, immunization, and exercise (Ouellet *et al*., 2019).Heat stress occurs when a cow's ability to disperse heat produced through normal metabolism is compromised, usually as a result of ambient temperature exceeding the thermo neutral zone (TNZ), which is defined as the temperature range wherein an animal maintains normal body temperature without altering metabolic heat production or employing evaporative heat loss mechanisms (Dahl *et al*., 2020).Heat stress is induced when a dairy cow is pushed above her TNZ at a Temperature Humidity Index of 68, forcing the cow to promote heat loss through sweating and panting and reduce heat production by limiting feed intake and decreasing milk production (Zimbelman et al., 2009). In lactating Holstein cows, the comfortable temperature is within the range of 4-24°C (Hahn, 1981). The effects of heat stress on the cows begin to be observed above 24°C, and milk yield decreases markedly above 27°C (Johnson, 1965).

Shelter management

The provision of cool water and shade to all dairy animals is a prerequisite for reducing heat stress. A well-designed shade can substantially reduce the total radiant heat load experienced by dairy animals. The absence of or inadequate housing and ventilation coupled with overcrowding and unhygienic conditions are likely to affect dairy animals' health and productivity (Kataktalware *et al*., 2017). An animal shelter must provide a comfortable, hygienic, well-drained lying area, protection from adverse weather. Further, adequate floor space is also required to allow the animal to move freely around without undue risk of injury and to express normal behaviour.

Structure: Physical structures that provide shade such as trees, roofs, or cloth can create more hospitable microclimates for cows because of the reduction in solar radiation exposure and a decline in ambient temperature (Polsky and Keyserlingk, 2017). Barn orientation (depending on geographic location) can also help mitigate heat stress by reducing the insolation and stall surface temperature, which in turn increase the heat transfer from the cow's body back to the environment (Angrecka and Herbut, 2016). The longer side of the dairy shelter with an east-west orientation reduces the amount of direct sunlight shining on the side walls or entering the house. Different types of materials like thatch, earthen tiles, corrugated iron sheet, asbestos sheet, iron sheets with aluminiumpaint, etc. could be utilized as roofing material to reduce solar radiation and shield the animals from precipitation or inclement weather conditions. Concerns exist regarding the transfer of radiant energy through metal roofs. The temperature at the underside of bare metal and insulated roofs differed by approximately 10°C during the peak heat of the day averaged over a 38-day period, and on the hottest day, the temperatures were 37 and 57°C under-insulated and uninsulated roofs (Buffington *et al*., 1983). The quality of shade material to a great extent determines the micro-climate of the animal house and should ideally be light, strong, durable, weatherproof, good looking, a bad conductor of heat and free from the tendency to condense moisture inside (Kamal *et al*., 2013). To minimize radiant heat load, white paint on the upper side and black paint on the underside of the metal roof can be applied. Shade cloths like woven polypropylene which are less expensive could also be considered as a roofing option as it provides about 80 to 85% as much shading. There is a beneficial effect of shade cloth on animal performance by minimizing the heat stress (Khongdee *et al*., 2010). The side curtains could be put up to prohibit direct sunlight from entering the animal shade. The west side of the animal house could also be fixed with side and vertical curtains. Fang (2007) described an alternative when no pads or fans are installed is to install an extra wall layer at either end. A fixed non-transparent curtain can be used as the outer layer. The outer layer should be 10 cm away from the inside wall, with vertical openings at both ends. The bottom opening allows cold air to enter, and the upper opening allows hot air to exit. The ten-centimetre of air between the two walls provides a thermal barrier to prevent conductive thermal energy from entering the house. This is the cheapest double-wall approach and is a proven technology in structural design (Fang, 2007).



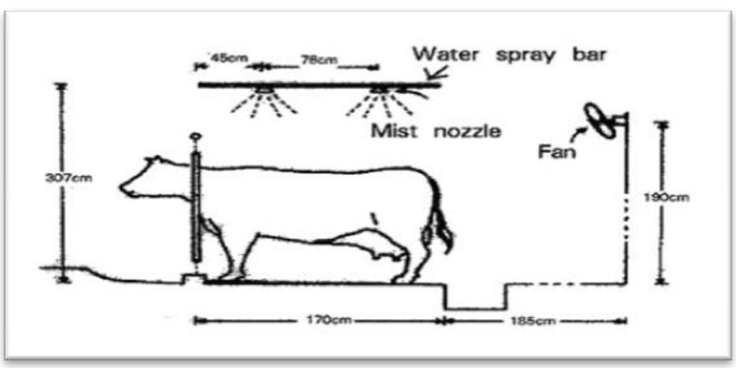
Sun anglesofan east-west oriented freestall barn (Source: Smith et al., 2006)

Ventilation: A well-ventilated animal shelter is essential for providing fresh, clean air to animals as well as workers. Dairy animals regularly require an optimal microclimate to achieve and maintain their health and production efficiency. High moisture levels, harmful manure gases, and other microorganisms prevailing in unventilated or poorly ventilated animal shelters create a harmful environment affecting milk yield and quality.

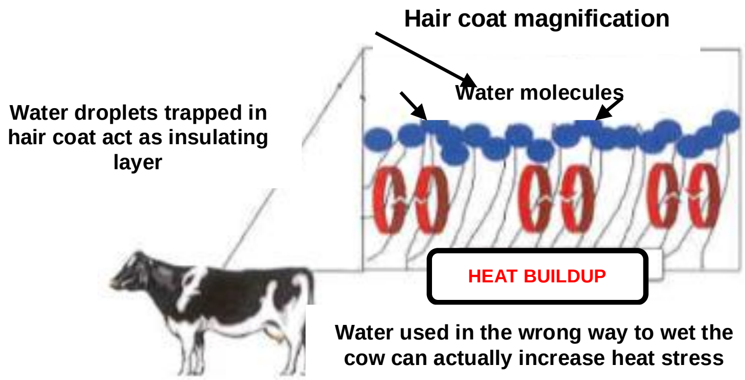
Outer coverings and shading, perhaps combined with a roof spray, are popular greenhouse technologies to reduce the height of the eaves. Various roof systems give improved natural ventilation employing roof openings, enhanced solar chimney effect, etc. A roof vent is necessary for an open type dairy shed to allow heat to escape from the upper part of the shed. With the traditional open-roof structure, the key factors for natural ventilation include the size of the roof opening concerning the floor area and the vertical distance between the air inlet and outlet. For example, a house six meters wide requires a roof vent at least 30 cm wide (Fang *et al*., 2007). For a closed type dairy barn, pads and fans may be installed at both ends. Much of the emphasis on environmental modification has focused on the use of free-stall and loose housing barns with high, steeply pitched (4 in 12 pitch) roofs, often with open or capped ridge vents. These barns minimize the transfer of infrared radiation due to the high roof, encourage a venturi effect due to the rising of hot air up the roof incline and exiting the ridge vent, and also encourage cross-ventilation from wind moving through the barn because of the high eaves (West, 2003).

Fans: Fan installations, which facilitate air movement and increase convection, have been used to reduce environmental temperatures and mitigate heat stress by decreasing the respiratory rate and rectal temperature and increasing dry matter intake (Armstrong, 1994). Fixing the fans at strategic places is necessary to ensure that animals are benefitted from the additional cooling facility. It has been suggested that in holding areas and free stall shelters the fans should be installed longitudinally, spaced not more than 10 times their blade diameter. Fans should be located vertically and just high enough so that they are out of reach of the cattle and do not interfere with alley scraping or bedding operations (Shearer *et al.*, 1991). If air is flowing over the animal with a velocity between two and three meters per second, it increases convective heat loss during stressful conditions. The floor area should be larger than the roof area so that the animal can move to avoid the direct sun (Bucklin *et al.*, 1991). The minimum height of the roof should be 3.6 m (4.3 m if wider than 12.2 m) for sufficient air movement in the centre of the shade (Buffington *et al.*, 1981).

Sprinkler and fan cooling: The perusal of scientific literature revealed that different water application rates resulted in different physiology and productivity responses from dairy animals. An 11.6 percent improvement in milk yield had been recorded when cows were sprayed for 1.5 min of every 15 min of operation (Strickland *et al.*, 1989). Cooled dairy cows had significantly reduced the respiratory rate (57 versus 95 breaths/min), and improved efficiency of production (kg milk per kg DMI), which could be due to lower energy expenditures for body cooling. Day-long cooling in the free-stall barn provides for continuous cooling, minimizing the elevation of body temperature during the day. The frequency of wetting and duration of cooling is critical to the effectiveness of cooling systems. Wetting cows for 10 seconds was less effective in cooling cows than wetting for 20 or 30 seconds, which were similar (Flamenbaum *et al.*, 1986), while cooling for 15, 30, and 45 minutes reduced the rectal temperature by 0.6, 0.7, and 1.0°C, respectively which indicates that the duration of time for both fans and wetting had considerable effects on the amount of cooling achieved. The cooling system used by Strickland *et al.* (1989) required 454.2 L/cow/day, which totalled 54,504 L/cow for a 120-day cooling season. Large droplets from a low-pressure sprinkler system that completely wet the cow by soaking through the hair coat to the skin were more effective than a misting system (Armstrong, 1994). As the sprinkler unit requires nearly 10 times more water than the mist unit, it is necessary to utilize a large volume of wastewater judicially. Some recent work has looked at providing cows with self-controlled showers (which animals can operate using a pressure-sensitive floor), which provide cooling on an individual animal basis but have the added benefit of reducing overall water usage by the group (Legrand *et al.*, 2011).



Mist water cooling (Source: Swailes, 2021)



Insulating effect of water (Source: Bass, 2015)

Evaporative cooling:

If the ambient temperature exceeds the animal's body temperature the evaporative cooling of the air may be required. Evaporative cooling system uses high pressure, fine mist and large volumes of air to evaporate moisture and cool the air surrounding the dairy animals. The farms in hot dry regions where the availability of water is inadequate, the evaporative cooling system could be useful. Evaporative cooling systems have been reported to improve the environment for lactating dairy cows in arid climates (Ryan *et al.*, 1992), and the reduced air temperature results from the removal of heat energy required to evaporate water. Evaporative cooling can be accomplished by passing air over a water surface, passing air through a wetted pad, or by atomizing or misting water into the air stream (West, 2003). However, the effectiveness of evaporative systems in climates with high relative humidity is not satisfactory. Berman (2006) found that a higher air velocity on the body surface of the animal may help to prevent humidity stress in sheltered areas in which the exposed body surface is reduced, such as mangers and stalls which may extend the use of evaporative cooling to less dry environments. Zone cooling is a form of evaporative cooling which incorporates the use of high-pressure mist injected into the fan stream, with fans directed downward to blow cooled air on the cow. Air conditioning and zone cooling are effective in cooling dairy animals but are cost-prohibitive. Therefore, the animal shelter should be well-designed to offer maximum comfort to dairy animals.

Cold stress

During a period of cold wave stemming after a snowfall in the western Himalayas, many places of northern and eastern India experience the ambient temperature of $0^{\circ}C$ for varying duration, the effect of cold stress on animal productivity and efficiency becomes evident (Kataktalware and Reddy, 2015). Wind chill and rain may reduce the animal's effective temperature to below its critical level, resulting in a decrease in weight gain and milk yield and increases in milk fat (Tarr, 2007). The newborn calves, calving cows, animals in low body condition, and sick animals are at the highest risk of cold stress. At least the cold-susceptible younger animals (up to one month of age) should be provided with some form of winter shelter. In the colder region, the use of the warmth and insulation provided by baled straw or hay for calf housing has been recommended by Thomas and Sastry (1991). The authors further suggested for plantation of trees for protection from wind in a north-south direction to protect from north and southwesterly winds.

Conclusion

Maintenance of health and improving the performance of dairy animals under hostile environmental conditions is one of the biggest challenges of the present time. The climate change being the reality, it is high time to sensitize the dairy farmers on adaptation strategies like shelter management. A properly designed animal house can contribute to harnessing the genetic potential of animals and increasing the profitability of dairy farms.

Note: The content of the lecture notes is prepared as reference material sourced mainly from Kataktalware et al (2018), various articles, online sources, etc. and purely for education and training of the participants of the Online Training Programme.

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ICAR-National Institute of Animal Nutrition and Physiology (ICAR-NIANP), Bengaluru
&
National Institute of Agricultural Extension Management, Hyderabad