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paper

BALANCED FEEDING FOR IMPROVING LIVESTOCK PRODUCTIVITY

Increase in milk production and nutrient use efficiency and decrease in methane emission

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BALANCED FEEDING FOR IMPROVING LIVESTOCK PRODUCTIVITY

Increase in milk production and nutrient use efficiency and decrease in methane emission

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Executive Summary

It is estimated that the world food requirement by the year 2050 will be double that of 2010. A significant part of this requirement will emanate from the developing countries, on account of increased human populations, disposable incomes and urbanization. For livestock products, about two-thirds of this increased demand will need to be met by improving the production efficiency of feed, both forages and concentrate feeds. However, in addition to shortage of feed, it is well documented worldwide that imbalanced nutrition is a major factor responsible for low livestock productivity. Balanced nutrition contributes to improving animal output as well as to reducing both the cost of production and the emission of green house gases per unit of animal product.

The National Dairy Development Board (NDDB) of India has developed user-friendly computer software for advising milk producers on their doorstep to balance the ration of their lactating animals with the available feed resources and area-specific mineral mixtures. In order to balance rations in the field, 'Nutrition masters' were created. These 'Nutrition masters' have data on the chemical composition of commonly used feed ingredients across various agro-climatic regions and on the nutrient requirements of lactating cows and buffaloes for milk production and other physiological functions, such as maintenance, and pregnancy. Identified officers from the grass-roots implementing agencies (dairy cooperative unions/federations, Non-Government Organizations (NGOs), service providers and producer companies) are trained by the NDDB on the preparation of balanced rations, and they are responsible for training the village-based local resource persons. The programme is implemented on the ground with the help of these resource persons. Data generated so far from approximately 11 500 animals in seven locations indicate that feeding a balanced ration can increase net daily income by 10–15 percent for those having one-two cows and/or buffaloes. This is through an increase in milk production and a decrease in the cost of feeding. The milk production efficiency (Fat Corrected Milk yield/feed dry matter intake) for cows before and after ration balancing were 0.58 and 0.78 kg/kg respectively and for buffaloes the corresponding values were 0.53 and 0.66 kg/kg, implying that more milk was produced from one kg of feed when using balanced rations. Feeding a balanced ration to dairy animals for sixty days, reduced faecal egg counts of internal parasites significantly (P <0.05; n = 9) from 184 ± 1.73 to 77 ± 1.59 per gram. Levels of serum immunoglobulins: IgG, IgM and IgA increased from 13.1 to 22.3, 3.2 to 3.6 and 0.72 to 0.96 mg/ml, respectively; suggesting improved animal immunity. Furthermore, feeding balanced rations was estimated to reduce enteric methane emissions by 15–20 percent per kg of milk produced. Large scale implementation of such programmes can help improve the productivity of livestock in developing countries. Similar approaches can also be adopted for growing and beef animals, taking into consideration local feeding and management conditions. Concerted efforts are required in other regions and donor participation in the programme will be catalytic to delivering the benefits of the ration balancing programmes to farmers. In addition, implementation of such a programme at the grass-roots level will enhance resource use efficiency and decrease the release of environmental pollutants from livestock production systems.

Introduction

The projected growth in annual income, urbanisation and of the human population in developing countries suggests that the future demand for milk and meat in these countries will increase substantially. By 2050 the global demand for dairy and meat is projected to increase by 74% and 58% respectively, and a large part of this demand will originate from developing countries. The global population of cattle in 2000 was 1.5 billion and that of goats and sheep was 1.7 billion. Models project that by 2050, the numbers will be 2.7 and 2.6 billion respectively. Annual demand for coarse grains for animal feed is also projected to increase over the period by 553 million tonnes, corresponding to approximately half of the total increase in demand (FAO, 2009). To meet the future demand, production of milk and meat, including milk production per lactating cow and daily weight gains for meat animals would need to be increased significantly if the available feed resources are to be sufficient.

Feed shortages notwithstanding, considerable potential exists to increase production levels across the range of growing, milch and beef animals by addressing the problem of imbalanced nutrition. The limited data on improving milk production efficiency in dairy animals through balanced feeding suggests that there is considerable scope for the enhancement of milk production with the existing feed and animal resources. This can be made possible through the transfer of scientific knowledge, in an easy to use and easy to implement manner to rural milk producers. The aim should be to promote feeding of a balanced ration in sufficient quantities and containing all essential nutrients. To promote this, various initiatives taken by the Dairy Board of India are described, many of which are relevant beyond India.

Productivity of dairy animals in India

There has been only modest improvement in the productivity of indigenous cows, crossbreds or buffaloes over the last two decades in India (Table 1). The average daily milk production data at 6.52 kg for crossbreds, 2.10 kg for indigenous cattle and 4.44 kg for buffaloes (NSSO, 2007) suggests that the productivity of these animals is far below their genetic potential. Added to this, the in-milk animals as a percentage of the total breedable population, is also very low, as noted by Basic Animal Husbandry Statistics (BAHS, 2010), which reported that at any one time an average of 46 percent of the total breedable population were dry. This is attributed in part to the deficiency of critical nutrients in the ration. Low productivity of animals with higher genetic potential can be primarily attributed to the imbalanced and inadequate feeding. According to Cunningham (2005), "genetics has created the potential, nutrition has failed to deliver that potential," irrespective of the type of system practiced.

In India, rice, wheat and maize yields per hectare of land have increased three to four fold between 1950 and 2010, mainly due to the adoption of improved agronomic practices. Egg production now ranges between 310–320 per annum per bird. Similarly, feed conversion efficiency in broilers is also at par with developed nations and Indian poultry farmers are now more conscious of the need to increase profits by cutting costs and improving productivity. Balancing of nutrients in poultry rations along with improved mineral supplementation has led to this improved productivity. However, the performance of ruminant livestock remains poor when compared with that being achieved in the developed world.

Imbalanced feeding leads to excess feeding of some nutrients whilst others remain deficient (Photo 1). This not only reduces milk production and increases costs per kg milk, but also affects various physiological functions including long term animal health, fertility and productivity. To ensure improved productivity it is necessary to augment and secure feed resources through short and long term planning. It is also essential that milk producers feed their animals the nutrients in amounts that match the physiological needs and objective of keeping the animal. Where possible locally available feeds should be used. Since many smallholder farmers do not have the necessary skills and knowledge to prepare balanced rations, this can be achieved through providing ration balancing advisory services direct to the farmer through village based trained local resource persons.

TABLE 1
In-milk animals as percent of the total breedable population and average productivity over the years in India

	1987*	1992*	1997*	2003*	2007*
BREEDABLE ANIMALS			*(millions)*		
Indigenous cows	62.03	62.49	64.45	60.15	59.23
Crossbred cows	6.03	6.41	10.67	14.06	15.55
Buffaloes	42.35	47.07	52.60	57.87	59.23
Total	**110.41**	**115.97**	**127.72**	**132.08**	**131.09**
IN-MILK ANIMALS			*(millions)*		
Indigenous cows	26.11	26.19	27.38	27.63	28.25
Crossbred cows	3.29	3.39	5.96	8.17	9.46
Buffaloes	22.61	25.19	28.41	33.32	33.16
Total	**52.01**	**54.77**	**61.75**	**69.12**	**70.87**
			(%)		
IN-MILK ANIMALS OF THE TOTAL BREEDABLE POPULATION	47.1	47.2	48.4	52.0	54.0
MILK PRODUCTION (average)**			*(kg/animal/day)*		
Indigenous cows	1.73	1.76	1.83	1.92	2.10
Crossbred cows	5.04	5.65	6.36	6.53	6.52
Buffaloes	3.29	3.57	3.83	4.24	4.44

Source: *Indian Livestock Census, 1987, 1992, 1997, 2003 & 2007
**Reports of the Technical Committee of Direction for Improvement of Animal Husbandry and Dairying Statistics, 1990 & Basic Animal Husbandry Statistics (BAHS), 1987–2008.

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Photo 1
Animals fed on imbalanced ration

A balanced ration and ration balancing programme

A balanced ration should provide protein, energy, minerals and vitamins from dry fodders, green fodders, concentrates, mineral supplements etc., in appropriate quantities to enable the animal to perform optimally and remain healthy.

Imbalanced feeding results in:

- Low milk production, poor growth and reproduction
- Milk production of animals lower than their genetic potential
- Shorter lactation length and longer calving intervals
- Animals more prone to metabolic disorders such as milk fever and ketosis
- Slow growth in young animals and delayed age at first calving
- Shorter productive life
- Excessive amounts of pollutants released into the environment
- Lower profit to farmers

Based on our experience, it is evident that milk producers could be advised to balance the ration of their animals using locally available feed resources with the help of software developed by NDDB (Photo 2), using desktops, laptops or Personal Digital Assistants.

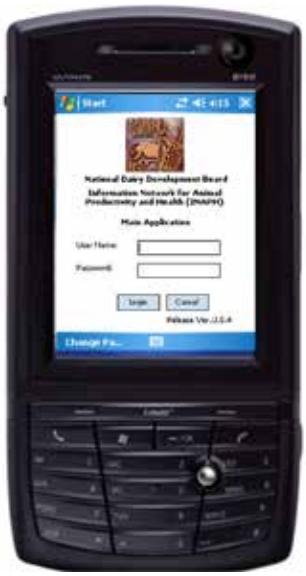

Photo 2
Personal Digital Assistants loaded with the ration balancing software

The programme comprises a feed data library and various 'Nutrition masters'. To create the feed data library, a wide range of feed ingredients including green and dry fodders, tree leaves, grains, oil cakes, agro-industrial by-products etc. were collected from different agro-ecological zones of the country and analyzed for chemical composition and nutritive value. Simultaneously, existing national and international feeding standards for nutrient requirement of growing, lactating and pregnant animals were used to create a range of 'Nutrition masters' containing nutrient requirements for various physiological stages: growth, lactation and reproduction, etc. Nutrition masters contain information on dry matter requirements, concentrate to forage ratios, and requirements for maintenance, growth, milk production and pregnancy for both cattle and buffaloes. Examples of 'Nutrient masters' are given in Tables 2–4.

Dry matter (DM) intake of the animal is very important for feed formulation. The programme sets the DM intake range depending upon the profile of the animal. Criteria used by the software to decide the range of DM intake is given in Table 3.

Concentrates and forages contribute to the dry matter in a ration. The ratio of these two is very important, as high levels of will lower ruminal pH, resulting in a depression in milk fat and predisposing the animal to some metabolic disorders. In tropical countries dairy animals

TABLE 2
Nutrition master for nutrient requirement

Type of ration	Nutrient requirements
Maintenance ration	Every animal needs a maintenance ration depending upon its type[1], class[2] and body weight.
Milk production ration	Lactating animals need extra feed, above maintenance depending upon the quantity of milk they produce and the percentage of fat in the milk.
Growth ration	Growth requires an extra 20 percent of the maintenance ration, if the animal is 3 years old or less. If over 3 years and under 4 years, 10 percent extra is needed but for an adult animal over four years of age a maintenance diet is sufficient.
Pregnancy ration	An animal is eligible for extra feed in the last 2 months of pregnancy. The quantity will depend on the feed available and type, class and body weight of the animal.

[1] Type: cow or buffalo
[2] Class: heifer or adult; Breed: Gir, Kankrej, Crossbred, Murrah, Jaffarabadi, Mehsani; sex: male or female; lactation status: dry or lactating

TABLE 3
Nutrition master for dry matter intake

Type	Milking	Months after calving	Dry matter range in kg as percent of body weight in kg
Cow/ Buffalo	No	-	2.0–3.0
Cow/ Buffalo	Yes	<= 2.0	2.0–3.0
Cow/ Buffalo	Yes	2.0–3.0	2.0–3.0
Cow/ Buffalo	Yes	3.0–24.0	2.0–3.5

TABLE 4
Nutrition master for concentrate to forage ratio in the ration

Type	Milking	Milk range (kg)	Percent concentrate dry matter of the total dry matter intake
Cow/ Buffalo	No	-	< 30
Cow/ Buffalo	Yes	<= 5.00	< 40
Cow/ Buffalo	Yes	5.0–10.0	< 50
Cow/ Buffalo	Yes	10.0–15.0	< 60
Cow/ Buffalo	Yes	15.0–25.0	< 70

are primarily fed on crop residue based diet with very little green fodder/hay/silage, which if available may only be for a limited time. These by-products have very low nutritive value and intake is limited. Thus, to meet the nutrient requirement of animals for body maintenance and milk production concentrate feed ingredients are necessary. However, the quality of concentrate feeds vary from region to region. In some regions, protein meals are the major source of concentrate, whereas, in other locations it could be cereal brans or other by-products. Because of this, diets are nutrient-rich for the expected level of production. Crop residues are also low in energy content, which also has to be supplied from concentrate feeds. Crop residues are also poor source of minerals. In addition, certain feeds contain anti-metabolites such as oxalates, silicates, phytates, gossypol etc. which further limit the bio-availability of minerals from the gastro-intestinal tract. In view of this, more focus has been given to mineral supplementation. Also, in the tropical countries energy content of basal feeds, which are primarily crop residues, is low. Most of the energy requirement is met from the concentrate feeds which are over-fed in some situations, at the cost of mineral supplement. The ratio of concentrate and forage in the diet corresponding to different milk yields is given in Table 4.

Animals fed on concentrate-rich diets (> 60%), may go off-feed due to ruminal acidosis. A low pH is detrimental to the rumen fibre digesting bacteria which may cause a depression in fat content in the milk. It can also affect the animal's health status. In such cases, use of a buffer is recommended comprising sodium bi-carbonate and magnesium oxide (3:1) to be fed @ 50–75 g per animal per day. Alternatively it is possible to introduce some longer physical fibre into the ration (e.g. paddy straw) to promote rumination and saliva production. Buffers, either provided in the ration or produced by the cow resist a change in rumen pH by neutralizing the acids that are produced by fermentation and metabolism. Supplementing buffers help in maintaining rumen pH, reducing incidences of rumen acidosis and maintaining the fat content of the milk.

NDDB, with the help of a software company, developed an Information Network for Animal Productivity and Health (INAPH). It is a windows based internet linked application to assess the prevailing nutrient status of animals against the requirements and to determine a least cost ration with the available feed resources, including minerals. The software is compatible with computers, laptops and net books. The application can also be used on Personal Digital Assistants for areas devoid of internet connectivity. Data flow in Information Network for Animal Productivity and Health is depicted in Photo 3.

Ration balancing programme involves following steps:

Registration of animals. Farmers are selected based on their willingness for implementing the ration balancing programme. Animals yielding 5 litres and higher milk per day identified for the ration balancing programme are first ear tagged with a unique 12 digit number. Details of the animal, e.g. species, breed, age, milking status (lactating/dry), number of calvings, last calving date and pregnancy status are captured. Along with the animal's details, the owner's profile, e.g. name, father's name, age, village, village institution, tehsil (block), district and state are also noted. After completing all the information, the animal is registered on the server. Animal registration is a once-only activity.

Assessing nutrient status of animals. After registration, the animal's daily feed intake, daily milk yield and milk fat percent are recorded. In addition, the animal's body weight is also recorded. Based on milk yield, milk fat percent, body weight and the pregnancy status, the animal's nutrient requirement is computed by the software. Considering the prevailing feeding practices (feed intake), consumption of nutrients, e.g. energy (TDN; total digestible nutrients), protein, calcium and phosphorus is assessed. This information helps in understanding the deficiencies/excesses of various nutrients in the ration and the cost of milk production per kg of milk.

Formulating least cost rations using locally available resources. Based on the chemical composition of available feed resources (a pre-requisite to this is the preparation of inventories of feed resources that are used in a region) and in accordance with the nutrient requirement of the animal, the software computes the least cost ration within the given constraints. These constraints could include non-availability or limited availability of green fodder and/or compound cattle feed, affordability of milk producers to purchase specific feed ingredients from the market, roughage to concentrate ratio, stage of lactation and type of feed offered etc. The least cost ration, with suggested feed ingredients in proportions as indicated by the software, is designed to reduce the costs of feeding and/or increase milk production.

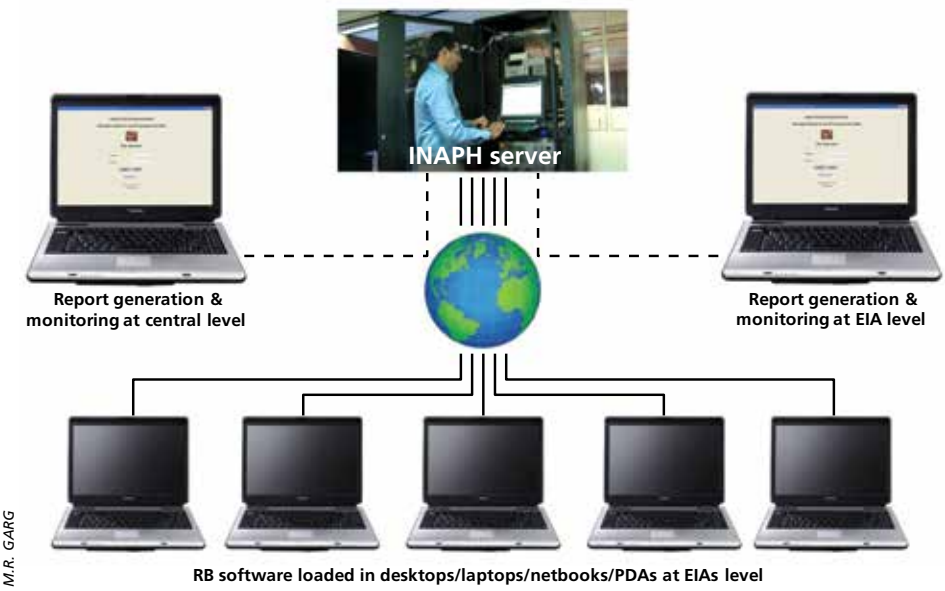

Photo 3
Data flow in Information Network for Animal Productivity and Health (INAPH)

Implementation of the ration balancing programme

NDDB has initiated multi-state implementation of the ration balancing programme on a large scale across the country through various implementing agencies with adequate infrastructure and manpower. The End Implementing Agencies (EIAs) could be dairy cooperatives, service providing organizations, state animal husbandry departments, producer companies and Non-Government Organizations (NGOs). NDDB imparts training to the identified technical officers and trainers of implementing agencies on the latest concepts of animal nutrition and the ration balancing programme software.

During the orientation of Chairmen and Secretaries of Dairy Cooperative Societies to the ration balancing programme, the process of selection of a local resource person is also discussed. The Management Committee of Dairy Cooperative Societies passes a resolution related to: 1) willingness of Dairy Cooperative Societies to participate in the ration balancing programme; 2) selection of the local resource person and sending him/her for the ration balancing programme training; and 3) starting the advisory services. Dairy Cooperative Societies notify the vacancy of the local resource person, giving details of minimum qualification and other eligibility criteria. One local resource person is expected to cover about 60 families in a village. Prospective candidates submit the completed application form to Dairy Cooperative Societies. The Management Committee of Dairy Cooperative Societies shortlists and recommend candidates based on the selection criteria to the Technical Officer. The Technical Officer from the End Implementing Agency then arranges a simple written test and oral interview of all shortlisted candidates and selects one potential local resource person for the village. After selection of the local resource person, Dairy Cooperative Society executes a contract with the successful candidate, describing the terms and conditions, valid for a period of 3 years. Identified local resource persons from various Dairy Cooperative Societies are trained in batch sizes of 10–15 participants. The training is provided by the trainers of the End Implementing Agency. The duration of the local resource person training is two weeks, one week of theoretical training and one week of in-field training. In the theory training, basic aspects of animal feeding and software handling are covered in the local language. In the field training, local resource persons are shown actual formulation of balanced rations on farm, using locally available feed resources.

Technical Officers and trainers identify potential villages and village based local resource persons who are well versed with dairy husbandry practices, to implement the programme on farm. The training elements covered in each of these aspects are given below.

THEORETICAL TRAINING

Animal feeding

- Basic aspects of animal nutrition
- Chemical composition of commonly available feeds and fodder
- Photographs of feeds and fodder, their local name and English name
- Nutrient requirement of different categories of dairy animals
- Introduction of the ration balancing programme and advantages of feeding a balanced ration
- Showing a documentary on the ration balancing programme in appropriate local language
- Different aspects of feeding and management of animals, including de-worming
- Significance of area-specific mineral mixtures in improving animal productivity
- Showing a documentary on importance of feeding minerals to dairy animals
- The importance of rumen function as the prime driver of milk production
- Importance of bypass protein and bypass fat supplements for increasing milk production
- Different types of feeds for different categories of animals, including milk replacer and calf starter for young calves
- Importance of green fodder for dairy animals
- Different constraints in feeding of concentrates and roughages.

Theoretical training starts with an explanation of the digestive system of ruminants and how ruminant animals are different from non-ruminants. Diagrammes of the digestive system of ruminants in power-point slides as well as video clips on the digestion and absorption of different nutrients is also shown during the training. The session on animal feeding includes name, identification, class of feed, major sources of nutrients, i.e. energy and protein, dry matter content, palatability, digestibility, intake etc. for each concentrate feed ingredient, and dry and green roughages commonly fed to animals. The intake of different feeds and fodder from concentrates and roughages is also explained in the theoretical session on formulation of least cost balanced ration. Towards the end, a video in the regional language is shown covering various aspects of the programme, including its implementation.

Software handling

- Demonstration of the ration balancing programme software
- Start and shutdown of the personal digital assistants/Notebooks/Netbooks or any hand held device to avoid loss of data;
- Use of the software through the Internet;
- Downloading of the software and location of the software on hand held devices, and handling of different functions of the ration balancing programme software;
- Different screens for the ration balancing programme software and their utility, including animal registration with examples and actual screen snapshots;
- Selection of different ingredients from the software data library;
- Entering of different constraints for dry fodder, green fodder and concentrate feed ingredients;
- Location of output file, i.e. of least cost ration formulation;
- Synchronization of data from hand held device to the central server;
- Frequently encountered problems and their solutions.

FIELD TRAINING

Field demonstrations

- Selection of animals for the ration balancing programme and demonstration of ration balancing on farm;
- Animal handling under field conditions;
- Demonstration of ear tagging and precautions to be taken;
- Measurement of body weight (Photo 4), and weighing of feeds and fodder;
- Measurement of milk production and collection of milk sample for fat analysis;
- Discussions on the difficulties faced during implementation of the ration balancing programme in the field and likely solutions;
- Discussions with the milk producers of the availability of feed resources and mineral mixtures;
- Explanation on how to feed a least cost ration regularly and follow up activities with milk producers, records keeping in the specific formats;
- Collection of feedback from milk producers;
- Synchronization of data to the central server and likely difficulties faced under the field conditions and their solutions.

Technical Officers and local resource persons conduct village level meeting in the local language to discuss with the farmers the importance of the programme and identify suitable beneficiaries. Local resource persons visit every farmer to select animals and ear tag

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Photo 4

Local resource person measuring heart girth of ear-tagged animals under the ration balancing programme

them for data recording. They also collect milk samples for analysis of milk fat, measure daily milk yield, weigh feed ingredients fed, record animal profile and current feeding details to formulate a balanced ration by readjusting the available feed resources at least possible cost. The formulated balanced ration is provided to the farmers in a prescribed format in the local language. The local resource persons revisit the farmers after 3 to 4 weeks or whenever there is change in feed ingredients and re-formulation of a balanced ration is required. They ensure that the farmers feed the balanced ration to their animals. All the data synchronised by the local resource persons are stored on a central server. Data synchronization is the process of establishing consistency among data from a source to a target data storage and vice versa and the continuous harmonization of the data over time. This helps to assess nutrient status, cost of milk production, lactation length and lactation yield of different categories of animals. The aspects covered are:

- Animal-wise and village-wise ration balancing programme impact report;
- Animal-wise details of recommended balanced ration;
- Report on nutrient status of different categories of animals during different phases of lactation;
- Report on cost of milk production amongst different breeds, species, seasons and regions, among others; and
- Report on lactation length and milk yield during the entire lactation by indigenous cows, crossbred cows and buffaloes.

The information generated through the above reports helps in making operational decisions for enhancing the efficiency of dairy farming in a location or a region. Also the information generated could be used for policy and guideline formulation for sustainable development of the dairy industry in the region.

Along with the ration balancing advisory services, the local resource persons also educate the milk producers about the best practices of animal rearing and feeding practices. The technical officers and the supervisory staff regularly monitor the progress of the programme and the work carried out by the local resource persons. The features that are monitored and the tools used for monitoring these aspects are:

Features

- Regularity of field visits by the local resource persons
- Correct recording of data on farm
- Availability of mineral mixtures
- Minimum of 10 percent of the ration balancing advice given by the local resource persons to be cross-checked for their accuracy
- Level of farmer adoption of the advice given by the local resource persons
- Comparison of performance of each local resource person with that of others in the same locality

Tools

- INAPH-Management Information System (MIS) report
- Field visits
- Completed formats on ration balancing advice
- Farmers feedback
- Generation of periodic reports

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Photo 5
An officer explaining the concept of balanced feeding to milk producers

The local resource persons are paid Rs. 1 500 per month for the first year and Rs. 750 per month for the second year (US$ 1 = ca Rs. 52) and thereafter they become self-sustainable as they get commission from the sale of feed and feed supplements to the milk producers/farmers. If one local resource person covers 75 lactating animals in a village then he would need to sell more than 200 kg of mineral mixture per month. Given commission @ Rs 10 per kg, he should be able to earn more than Rs 2000 per month from the sale of mineral mixture alone. In addition, he can also sell de-wormer feed pellets, bypass protein/fat supplement, fodder seeds etc. and get additional income. Under the National Dairy Plan-I, it is envisaged to implement the ration balancing advisory services in about 40 000 villages spread over 14 major milk producing states, covering about 2.7 million lactating animals by 2016–17.

Impact of feeding balanced rations

INCREASE IN MILK PRODUCTION AND NET DAILY INCOME

The ration balancing programme has been pilot tested under field conditions in different states. So far, about 11 500 animals have been covered by the advisory services. The cost of milk production has been reduced by between Rs. 0.25 to 2.00 per kg with average daily milk yield per cow increased by 0.2 to 1.0 kg and milk fat content increased by 0.2 to 0.6 percent units. Solids-not-fat (SNF) percentage also increased in milk when cows were fed a balanced ration. Increases in net daily income ranged between Rs. 8 to 26 per animal per day. Through the ration balancing advisory services it has been possible to increase milk yield and reduce the cost of milk production (Table 5).

As shown in Table 5 animals fed a balanced ration showed improvements in daily milk production of 0.58 kg, in fat of 0.50 percent units and a reduction in daily feeding cost of Rs. 1.98 per kg milk. On average, there was increase in net daily income per animal of about Rs. 26 in cows and buffaloes yielding 8–9 kg milk, which translated into an increase in net daily income per animal of about 10%.

Currently, the ration balancing programme is being implemented in Banaskantha district of Northern Gujarat. About 3,100 lactating cows and buffaloes have been involved so far under the programme in 50 villages with the help of the local resource persons. Animals fed on balanced rations showed improvements in daily milk production of between 0.25–1.50 kg, in fat of 0.15–0.60 percent units and reduction in daily feeding cost of Rs. 0.95–1.65 per kg milk. On average, there was an increase in net daily income per animal of Rs. 16–24, in animals yielding 7–10 kg milk.

The size of response in milk production as a result of ration balancing advisory activities mainly depends on type of animal, breed, stage of lactation and farmer compliance. Breeds

TABLE 5
Effect of implementation of the ration balancing programme (RBP) on milk yield, milk fat and feeding cost in cows and buffaloes

Parameter	Before RBP	After RBP (average of 4 months)
Milk yield (kg/day)	$8.25^{a} \pm 0.04$	$8.83^{b} \pm 0.04$
Milk fat (%)	$5.79^{a} \pm 0.03$	$6.29^{b} \pm 0.03$
Feeding cost per kg milk yield (Rs.)	$9.4^{b} \pm 0.04$	$7.47^{a} \pm 0.04$

n = 2536
[a,b] Means with different superscripts in a row differ significantly (Garg, Biradar and Kannan, 2009).

with higher genetic potential are expected to respond better, in terms of increases in daily milk yield, to ration balancing. Similarly, responses in milk production are dependent on stage of lactation – animals in early lactation responding better than those in mid and late lactations. Other contributory issues are genetic potential and management, including cleaning of animals (important in tropical climate), adequate provision of fresh drinking water, parasitic load, presence of mastitis, among others. Subsequently, `challenge feeding' could also be tried to assess whether or not it is possible to increase milk production of animals in accordance with the genetic potential. The `challenge feeding' would be by giving an additional allowance of a balanced ration for a kg of milk. At this initial stage of the ration balancing programme it is not being attempted because the village based resource person may not able to handle all such issues without adequate experience and training. Another most important consideration is to ensure that the milk producers do not get disinterested at the initial stage of implementing of the ration balancing programme, which could happen if they do not see the benefits in proportion to their expenditure. This could occur while executing the `challenge feeding' once the benefits of the ration balancing programme are demonstrated to milk producers using their milking animals, then the ration balancing for growing calves and dry pregnant animals, and the `challenge feeding' would also be taken up.

INCREASE IN MILK PRODUCTION EFFICIENCY

Milk yield and milk fat content significantly (P <0.05) increased by 0.68 kg/day and 0.55 percent units in cows and 0.19 kg/day and 0.34 percent units in buffaloes, respectively, in the Northern region of India. In the Southern and Central regions of India, milk yield increased by 0.42 kg/day and 0.46 kg/day respectively in cows (P <0.05) after ration balancing. Milk production efficiency (kg Fat Corrected Milk yield/kg dry matter intake) of cows (n = 540) before and after ration balancing was 0.58 and 0.78 kg/kg respectively for cows. For buffaloes (n = 1025) these values were 0.53 and 0.66 kg/kg (Table 6). It was observed that more than 75 percent lactating animals were fed excess protein and energy, but the rations were deficient in minerals. When the rations of these animals were balanced, levels of protein and energy rich feed ingredients were restricted and the minerals were added to

TABLE 6
Effect of the ration balancing programme (RBP) on milk production efficiency

Parameter	Cow (n = 540)		Buffalo (n = 1025)	
	Before RBP	After RBP	Before RBP	After RBP
FCM yield (kg/day)	8.0[a] ± 0.1	8.7[b] ± 0.1	8.4[a] ± 0.1	9.2[b] ± 0.1
Average DMI (kg/day)	14.5[a] ±0.1	11.1[b] ± 0.1	16.4[a] ± 0.1	13.9[b] ± 0.1
FCM* yield (kg)/kg DMI	0.58[a] ± 0.01	0.78[b] ± 0.01	0.53[a] ± 0.004	0.66[b] ± 0.003

FCM, fat corrected milk
[a, b] Values with different superscript in a row differ significantly (P <0.01)
* 4% FCM & 6% FCM has been considered for cows & buffaloes, respectively.

the ration a reduction in dry mater intake and increase in milk production was noted. The increase in milk production efficiency after ration balancing resulted in more milk from the same amount of feed. This is in addition to a decreased cost of the inputs increased profit. Poor feeding of young calves leads to higher age at first calving and overall loss of productive life. Malnutrition also results in reduced vigour, poor immune response, suppressed vitality and higher susceptibility to diseases, ultimately leading to higher calf mortality. Most of the nutrients consumed over an animal's lifetime are used for maintenance. Hence, any reductions in age at first calving or dry period increase overall output per unit of nutrients. A balanced ration also helps in increasing daily weight gain in young calves, leading to earlier maturity and a younger age at first calving.

INCREASE IN RUMEN MICROBIAL PROTEIN SYNTHESIS

In low to medium milk yielding animals, microbial protein synthesis in the rumen plays a vital role in meeting protein and energy requirement of animals. In such animals the aim always is to optimize rumen fermentation so that dietary fiber digestion and microbial protein production are maximized (Makkar, 2004). On feeding a balanced ration, level of allantoins (mmol per litre) in urine of cows was significantly higher (187.97 ± 2.45; $P<0.05$) compared with the control group (10.85 ± 2.37). Level of allantoins in urine is an indicator of microbial protein synthesis in the rumen (Pimp *et al*., 2001; Makkar, 2004; Ramgaokar *et al*., 2008), and it has been used to estimate microbial protein synthesis in the rumen and subsequently digested in the lower gut of ruminants (Dipu *et al*., 2006). Microbial protein synthesis calculated from the excretion of urinary purine derivatives is presented in Table 7. Higher production of microbial protein observed after ration balancing shows better functioning of the rumen and saving of feed protein, the most expensive component of the diet.

TABLE 7
Effect of the ration balancing programme (RBP) on efficiency of microbial protein synthesis

Parameter	Cow (n = 30)		Buffalo (n = 26)	
	Before RBP	After RBP	Before RBP	After RBP
Microbial nitrogen yield (g N/day)	100.96[c] ± 6.32	139.32[d] ± 10.95	77.70[c] ± 4.21	111.62[d] ± 10.21
Efficiency of microbial protein synthesis (g MCP/kg DOM)	66.78[a] ± 4.83	83.37[b] ± 6.24	56.59[c] ± 3.39	78.29[d] ± 6.71

MCP, microbial crude protein; DOM, digestible organic matter
[a, b] Values with different superscript in a row differ significantly ($P<0.05$)
[c, d] Values with different superscript in a row differ significantly ($P<0.01$)

INCREASE IN IMMUNE STATUS OF ANIMALS

Imbalances of nutrients can also affect the activity of certain enzymes, thereby, impairing the overall immune function (Spears, 2000). In view of this, the impact of feeding a balanced ration on the immune status of field animals was evaluated. On feeding a balanced ration to Gir cows for sixty days, levels of serum immunoglobulin: IgG, IgM and IgA increased from 13.10 to 22.32, 3.19 to 3.60 and 0.72 to 0.96 mg/ml, respectively (Table 8), indicating that feeding balanced ration improves the overall immune status of dairy animals.

Minerals are required for the functionality of numerous structural proteins, enzymes and cellular proteins (NRC, 2001; Nocek, Socha and Tomlinson, 2006). Addition of minerals to the ration of dairy animals could be responsible for greater production of IgG thus affecting cell metabolism and resulting in a better immune status (Wedekind, Hortin and Baker, 1992). Subclinical or marginal deficiencies of minerals may be a larger problem than an acute deficiency (Tomlinson, Socha and DeFrain, 2007; Garg, Bhanderi and Sherasia, 2007) because specific signs of deficiency are not evident, however, the animal continues to grow, produce and reproduce but at a reduced rate (Larson, 2005). Animals fed excess protein can have a reduced conception rate. Energy is the major nutrient required by adult animals and inadequate energy intake has a detrimental impact on the reproduction efficiency of female bovines. Animals under negative energy balance can have extended periods of anovulation. Postpartum anoestrus, as well as infertility, are magnified by loss of body condition during the early post-partum period. Feeding balance diets of energy, protein and minerals should help in improving reproduction efficiency.

DECREASE IN PARASITIC LOAD IN ANIMALS

Animals fed on imbalanced diets frequently have a higher load of parasitic infestations that will utilise vital essential nutrients. Parasitic load in dairy animals affects growth, milk production and general health. In view of this, it is essential to know the parasitic load in

TABLE 8
Effect of feeding balanced ration on different biological and economic parameters in Gir cows

Particular	Parameter	Traditional ration (n = 9)	Balanced ration (n = 9)
Milk	Milk yield (kg/day)	8.74	9.37
	Fat (%)	3.94	3.95
	Protein (%)	2.90	2.99
Blood serum	IgG (mg/ml)	13.10	22.32*
	IgM (mg/ml)	3.19	3.60
	IgA (mg/ml)	0.72	0.96
	BUN (mg/dl)	12.60	12.76
Urine	Allantoin (mmol/litre)	10.85	17.97*
Faeces	Eggs per gram	184	77*
Feed	Average daily feeding cost per animal (Rs.)	97.27	78.15
	Feed cost (Rs.)/100 kg of milk production	1113	834

*$P < 0.05$

M.R. GARG

Photo 6
Collection of breath sample for methane emission measurement from a cow under field conditions

animals. With this aim, rectal faecal samples were collected from each cow for estimation of eggs per gram (EPG). These eggs were of mainly Ostertagia spp., Trichostrongylus axei, Haemonchus placei, Cooperia spp., Oesophagostomum radiatum, Bunostomum spp., Fasciola hepatica, Paramphistomes spp. and Schistosoma spp. of large ruminants. During the trial period, the intensity of infection in terms of faecal egg counts ranged from 80 to 280 EPG in control (before ration balancing) and 20–120 EPG in experimental (after ration balancing) groups, respectively. By feeding a balanced ration to animals, average EPG was reduced from 184 ± 1.73 to 77 ± 1.59 (Table 8). The interaction between the presence of parasites in the host organism and the level of nutrition has been the subject of many studies and an inverse relation exists between the number of gastro-intestinal worms and the level of nutrition – better nutrition decreases the load of intestinal worms (Fekete and Kellems, 2007).

DECREASE IN ENTERIC METHANE EMISSION

Animals on imbalanced rations not only yield less milk at a higher cost, but also are reported to produce more methane per litre of milk (Capper, Cady and Bauman, 2009; Garg, 2011). Collection of breath samples for methane measurement under field conditions is depicted in Photo 5. Methane emissions from cows before and after ration balancing in the Western region were 238 and 206 g/day, respectively, which was significantly (P <0.05) lower (Table 9), without affecting dry matter intake. Methane emissions from buffaloes before and after the ration balancing programme in this region were 232 and 200 g/day, respectively (Kannan and Garg, 2009). Methane emissions (g/kg milk yield) were significantly (P <0.01) reduced in the Western (17–20 percent) and in the Northern (17–21

percent) regions (Kannan, Garg and Singh, 2010) in cows and buffaloes. In the Southern and the Central regions, methane emissions (g/kg milk yield) reduced significantly by 13–15 percent in cows and buffaloes (Kannan, Garg and Kumar, 2011). Average reduction of 12 and 15 percent methane emissions (g/kg dry matter intake) were observed in lactating cows and buffaloes, respectively.

INCREASE IN EFFICIENCY OF FEED NITROGEN USE IN MILK

The efficiency of feed nitrogen use in producing milk (g nitrogen in milk/g nitrogen consumed from feed) in low (n = 148), medium (n = 280) and high (n = 11) yielding cows, before and after ration balancing, was 15.72 and 24.23; 18.77 and 26.40; 24.25 and 29.94, respectively. In low (n = 171), medium (n = 495) and high (n = 55) yielding buffaloes these values were 15.95 and 18.99; 18.99 and 20.14; 21.53 and 21.42. The increase in feed nitrogen to milk nitrogen secretion efficiency after ration balancing suggests that from the same amount of feed-nitrogen, higher amounts of milk protein were synthesised. This can help in saving feed resources and decrease nitrogen excretion into the environment.

TABLE 9
Effect of the ration balancing programme (RBP) on milk production and methane emission

Study	Species		Dry matter intake (kg/d)	Milk yield (kg/d)	Fat (%)	Methane emission (g/d)	Methane emission (g/kg milk)
Western region	Cows (*n* = 5)	Before RBP	12.5 ± 0.2	10.5^{a} ± 0.3	4.3^{a} ± 0.1	238^{a} ± 4.4	22.7^{c} ± 2.2
		After RBP	12.2 ± 0.2	11^{b} ± 0.3	4.6^{b} ± 0.1	206^{b} ± 1.5	18.8^{d} ± 2.0
	Buffaloes (*n* = 22)	Before RBP	12.7 ± 0.3	8.5^{a} ± 0.5	6.5^{a} ± 0.1	232^{a} ± 5.9	27.3^{c} ± 1.6
		After RBP	12.3 ± 0.4	8.9^{b} ± 0.4	6.8^{b} ± 0.1	200^{b} ± 5.0	22.4^{d} ± 2.4
Northern region	Cows (*n* = 13)	Before RBP	9.4 ± 0.1	4.9^{a} ± 0.1	4.2^{a} ± 0.1	196^{a} ± 5.74	39.5^{a} ± 1.7
		After RBP	9.7 ± 0.2	5.5^{b} ± 0.1	4.4^{b} ± 0.1	174^{b} ± 4.7	31.5^{b} ± 1.7
	Buffaloes (*n* = 13)	Before RBP	10.2 ± 0.2	5.2^{a} ± 0.1	6.0^{a} ± 0.1	215^{a} ± 7.1	40.9^{a} ± 2.2
		After RBP	10.3 ± 0.1	5.9^{b} ± 0.1	6.3^{b} ± 0.1	192^{b} ± 5.9	32.4^{b} ± 2.0
Southern region	Cows (*n* = 30)	Before RBP	10.5 ± 0.7	8.4^{a} ± 0.4	4.1 ± 0.1	187^{a} ± 4.6	22.2^{a} ± 2.4
		After RBP	11.6 ± 0.3	8.8^{b} ± 0.4	4.1 ± 0.1	166^{b} ± 3.9	18.8^{b} ± 1.8
Central region	Buffaloes (*n* = 26)	Before RBP	10.3^{c} ± 0.2	6.1^{c} ± 0.3	6.5^{c} ± 0.2	154^{c} ± 5.5	25.3^{c} ± 1.6
		After RBP	11.6^{d} ± 0.3	6.6^{d} ± 0.4	6.8^{d} ± 0.1	134^{d} ± 5.4	20.4^{d} ± 1.3

$^{a, b}$ Values with different superscript in a column differ significantly (P <0.05)
$^{c, d}$ Values with different superscript in a column differ significantly (P <0.01)

OVERALL BENEFITS OF THE RATION BALANCING PROGRAMME

- Efficient utilisation of locally available feed resources
- Improvement in milk production and quality (fat and solids-not-fat)
- Possible reduction in daily feeding cost
- Increase in net daily income
- Improvement in reproduction efficiency of animals
- Reduction in calving interval, and as a result increase in productive life
- Improvement in the growth rate of calves, leading to early maturity and earlier calving
- Reduction in parasitic load
- Better immune response, hence better resistance against diseases
- Reduction in methane emission
- Reduction in nitrogen excretion

Knowledge transfer to milk producers on other related aspects

It is essential that farmers are advised to balance the rations for their animals for energy, protein, and minerals using available feed resources, with or without compound feed. Along with the ration balancing advisory services, milk producers also need to be educated, through an efficient extension service, about the importance of drinking water quality, proper feeding mangers, colostrum feeding to newly born calves, suitable chaffing of fodder, de-worming, vaccination, timely insemination, among others. Some of these messages could be put across through regular group meetings with suitable follow up meetings wherever the ration balancing programme is being carried out.

Relevance of the ration balancing programme to other developing countries

The concept of ration balancing is already in place in most of the advanced countries where the feed resources are available in abundance, herd sizes are much bigger and the livestock owners are better versed with the scientific practices of feeding and management. However, in most of the developing countries, imbalanced feeding is one of the major factors responsible for low productivity. Considering its importance and relevance, concept of ration balancing can well be applied in developing countries for various production systems, including those rearing milch and beef animals. Considering the local situations and the production systems, different 'Nutrition masters' containing chemical composition and nutritive value of locally available feed resources, including various by-products of agriculture and allied industries, that are being fed or have the potential as animal feed must be created.

In view of the nutrient requirement of various categories of animals, software can be developed with the ability to provide balanced rations for growing, lactating and beef animals. Information on the chemical composition and nutrient requirements for various production functions can be generated with the help of local research institutes in individual countries and the desired software can thus be developed with the help of software companies. The ration balancing programme can be implemented by service providing organizations operating in different areas that have the village level network to reach the farmers thus offering them various strategic feed supplements at reasonable cost, essential for formulating a balanced ration. To ensure long term sustainability, the programme should preferably be implemented through a resource person from within the community who could be adequately trained and equipped.

The Food and Agriculture Organization (FAO) of the United Nations with the support of the Colombian Corporation of Agricultural Research (CORPOICA) organised an international Workshop in Villavicencio, Colombia from 25–27 October 2011 on 'Ration Balancing for Dairy Farms in Tropical Countries'. Several extension and livestock workers and researchers from various Latin American countries participated in the Workshop. The ration balancing programme being implemented by the National Dairy Development Board (NDDB) of India was demonstrated and explained in detail. Having realised the economic importance of the programme for enhancing daily income of livestock owners, the participants pressed for making available such a programme to Latin American countries. It was decided that CORPOICA would take a lead to develop this for Colombia with the help of local research institutes and the technical support of FAO and NDDB. Such a programme could possibly be replicated by other Latin American countries. Concerted efforts are required in other

regions. Donor participation in the programme will be catalytic to delivering the benefits of the ration balancing programme to farmers. In addition, implementation of such a programme at the grass-roots level will enhance resource use efficiency and reduce the release of environmental pollutants from livestock production systems.

Conclusions

Dairy animals in India and other tropical countries are fed mainly on by-products of various food crops, oil seeds and locally grown fodder. In some situations these by-products, especially oil seed cakes or meals are not available in sufficient quantity to meet the entire demand of the livestock population. Limited land available for meeting the needs of an ever growing human population in developing countries cannot be spared for growing additional green fodder and coarse grains for feeding livestock. Even the available resources are not utilized judiciously as the majority of the animals in these countries are fed imbalanced rations, resulting in milk yields below their genetic potential. If the increased demand for milk caused by an increase in population, urbanization and buying capacity is to be met, productivity of dairy animals must be improved coupled with greater efficiency of use of the available feed resources.

Since feeding alone accounts for more than 70 percent of the total cost of milk production, balanced feeding of dairy animals can play a pivotal role in a successful dairy development programme worldwide. To maximize profitability from the animals one needs to ensure that they receive the required quantity of protein, energy, minerals and vitamins, preferably from locally available feed resources. About 70 percent of the milk producers in India and other developing countries are landless and marginal farmers and the disposable income from milk contributes significantly for sustaining their livelihood. Nearly a 10 percent increase in net daily income per animal by propagating and applying the concept of balanced feeding on a large scale, could improve substantially the socio-economic status of the masses living below the poverty line. The ration balancing programme developed from known scientific principles is a unique approach and has high potential for increasing productivity. Large scale implementation of the ration balancing programme in tropical countries would not only help in increasing milk production and reducing daily feeding cost, but would also help in reducing methane emissions and nitrogen excretion into the environment.

Bibliography

BAHS. 2010. *Basic Animal Husbandry Statistics 2010.* Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries, Government of India, New Delhi. http://dahd.nic.in

Capper, J.L., Cady, R.A. & Bauman, D.E. 2009. *The environmental impact of dairy production: 1944* compared with 2007. J. Anim. Sci., 87:2160–2167.

Cunningham, E. P. 2005. *The genetic dimension.* Pages 9–11 in Knowledge Agriculture: Perspectives Towards a New Model of Milk Production. R. Keenan & Co., Co. Carlow,Ireland.

Dipu, M.T., George, S.K., Singh, P., Verma, A.K. & Mehra, U.R. 2006. Measurement of microbial protein supply in Murrah buffaloes (Bubalus bubalis) using urinary purine derivatives excretion and PDC index. *Asian-Aust. J. Anim. Sci.,* 19: 347–355.

FAO. 2009. *The State of Food and Agriculture.* Livestock in the Balance, FAO, Rome, Italy.

Fekete, S.G. & Kellems, R.O. 2007. Interrelationship of feeding with immunity and parasitic infection: a review. *Veterinarni Medicina*, 52 (4): 131–143.

Garg, M.R., Bhanderi, B.M. & Sherasia, P.L. 2007. Area specific mineral mixtures and vitamins in the ration of dairy animals for improved productivity and reproduction efficiency. *Indian Dairyman,* 59(8): 21–27.

Garg, M.R., Biradar, S.A. & Kannan, A. 2009. Assessment of economic impact of implementing ration balancing programme in lactating cows and buffaloes under field conditions. *Indian J. Anim. Nutr.,* 26(2): 146–150.

Garg, M.R. 2011. Methane emission reduction in lactating animals through balanced feeding. Proceedings of *Recent Advances in Methane Estimation and Mitigation Strategies in Ruminants.* NIANP, Bangalore, August 5–18, 2011, pp. 9–13.

Kannan, A. & Garg, M.R. 2009. Effect of ration balancing on methane emission reduction in lactating animals under field conditions. *Indian J. Dairy Sci.*, 62(4): 292–296.

Kannan, A., Garg, M.R. & Singh, P. 2010. Effect of ration balancing on methane emission and milk production in lactating animals under field conditions in Rae Bareli district of Uttar Pradesh. *Indian J. Anim. Nutr.*, 27(2): 103–108.

Kannan, A., Garg, M.R. & Mahesh Kumar, B.V. 2011. Effect of ration balancing on milk production, microbial protein synthesis and methane emission in crossbred cows under field conditions in Chittoor district of Andhra Pradesh. *Indian J. Anim. Nutr.*, 28(2): 117–123.

Larson, C.K. 2005. Role of Trace Minerals in Animal Reproduction. Nutrition Conference - Extension and University Professional and Personal Development. Dept Animal Sciences. University of Tennessee.

Livestock Census. 2007. *18th Livestock Census*. All India Report based on Quick Tabulation Plan. Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries, Government of India, New Delhi.

Makkar, H.P.S. 2004. Estimation of microbial protein supply in ruminant livestock through quantification of urinary purine derivatives. In: Makkar, H.P.S. and Chen, X.B. eds., Kluwer Academic Press, Dordrecht, The Netherlands, pp. 212.

Nocek, J.E., Socha, M.T. & Tomlinson, D.J. 2006. The effect of trace mineral fortification level and source on performance of dairy cattle. *J. Dairy Sci.*, 89: 2679–2693.

NRC. 2001. *Nutrient Requirements of Dairy Animals.* 7th Edn., National Academy of Science – National Research Council, Washington DC.

NSSO. 2007. National Sample Survey Organization. NSSO 61st Round. *Livestock productivity and ownership across operational land holding classes in India*, Department of Statistics, GOI.

Pimp, O., Liang, J.B., Jelan, Z.A. & Abdullah, N. 2001. Urinary excretion of duodenal purine derivatives in Kedah-Kelantan cattle. *Anim. Feed Sci. Tech.*, 92(3): 203–214.

Ramgaokar, J.S., Verma, A.K., Singh, P. & Mehra, U.R. 2008. Effect of dietary protein levels on urinary excretion and plasma concentration of purine derivatives in crossbred bulls. *Anim. Nutr. Feed Tech.*, 8(1): 18–25.

Spears, J.W. 2000. Micronutrients and immune function in cattle. *Proc. Nutr. Soc.*, 59: 587–594.

Tomlinson, D.J., Socha, M.T. & DeFrain, J.M. 2007. Cow immunity boosted with trace minerals. *Feed Tech. Magazine.* Vol. 11. No. 10. Available at http://www.allaboutfeed.net/article-database/cow-immunity-boosted-with-trace-minerals-id1254.html

Wedekind, K.J., Hortin, A.E. & Baker, D.H. 1992. Methodology for assessing zinc bio-availability: Efficacy estimates for zinc-methionine, zinc sulfate, and zinc oxide. *J. Anim. Sci.*, 70: 178–187.

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In developing countries feed shortages notwithstanding, considerable potential exists to increase production levels across a range of growing, lactating and beef animals by addressing the problem of imbalanced nutrition. The data on improving milk production efficiency in dairy animals through balanced feeding suggests that there is considerable scope for enhancing milk production with strategic use of the existing feed resources. This is possible through the transfer of scientific knowledge, in an easy-to-use and easy-to-implement manner to milk producers. The aim should be to promote feeding of a balanced ration in sufficient quantities and containing all essential nutrients. This paper outlines an approach used by National Dairy Development Board, India to balance rations at the doorsteps of smallholder farmers. This initiative has relevance for many other developing countries.

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