ISBN: 978-81-939050-1-2

Perspectives in Animal Nutrition 2018

A.K. Pattanaik, S.E. Jadhav
N. Dutta, A.K. Verma, Chandramoni (Eds.)

Animal Nutrition Approaches for Profitable Livestock Operations and Sustainable Rural Livelihoods

1.1

M. Blümmel✉, M.R. Garg[1], C. Jones[2], I. Baltenweck[2] and S. Staal[2]

International Livestock Research Institute
P.O. Box 5689, Addis Ababa, Ethiopia

✉ m.blummel@cgiar.org

Globally, livestock contribute 40% of agricultural GDP, and create livelihoods for more than 1 billion poor (Steinfeld *et al.*, 2006). From a nutritional standpoint, livestock contribute about 40% of the protein in human diets globally, and more than 50% in developed countries (FAO, 2017). As outlined in the livestock revolution scenario (Delgado *et al.*, 1999) consumption of animal products will increase particularly in low and middle income countries in response to urbanization and rising incomes. While the increasing demand for livestock products offers market opportunities and income for small holder producers and even the landless thereby providing pathways out of poverty (Kristjianson 2009), livestock production globally faces increasing pressure because of negative environmental implications particularly because of greenhouse gas emissions (Steinfeld *et al.*, 2006). Besides greenhouse gases, the high water requirements in some livestock production systems are a major concern.

Feed resourcing and feeding is at the very interface where the positive and negative effects of livestock, income, livelihoods and the environment are negotiated. Lack of affordable, reliable, and adequate feed (quantity and quality) represents a major constraint to smallholder competitiveness and the overall profitability of livestock production systems. Feed production and feeding are the major users of on-farm labour and very often it is the women who shoulder these responsibilities. Choice of feeds and feeding strategies also has major implications for natural resource usage and greenhouse gas emissions. For example, feed production can significantly deplete water resources, particularly in irrigated forage based systems. On the other hand, feed production, marketing and processing offers multiple business, income and employment opportunities for rural disadvantaged populations outside of the direct engagement in animal sourced food production (ASF).

The present paper therefore argues that the discipline of animal nutrition has a crucial role to play, and deserves greater attention, in livestock based livelihoods, than the other key technical inputs provided by animal health and genetics. The objectives of animal nutrition are therefore multi-fold: (a) increase the economic benefit from ASF production by decreasing feed costs and/or increasing ASF production and productivity, (b) decrease the environmental footprint of ASF production, (c) reduce labour requirements and drudgery involved in feed resourcing and feeding; and (d) provide opportunities for micro, small and medium enterprises (MSME) in feed production, marketing and processing to generate income and employment opportunities and while increasing the availability of affordable off-farm produced feed.

Feeds as a major input into animal-sourced food production

Proportion of feed costs in total production

Figure 1 depicts the proportion of feed costs in the total cost of dairy production across the globe in 2009. Globally feeds share of production costs ranges from less than 50% to more than 70%. India is one of the few countries where feed costs have been documented globally to amount to more than 70% of the costs of production.

Furthermore, over the past half-decade, feed costs in India have been rising more rapidly than the farm gate prices for milk. While costs for fodder and oil cakes increased annually by 9 and 10%, respectively, revenue from milk increased by only 6% (Source Ministry of Commerce and Industry GoI, Gain Report IN7123). This scissor effect, that is that feed costs rise substantially faster than farm gate prices for ASF, presents serious problems to farmers that if not checked, makes engagement in ASF production unattractive, a situation already observed in many low and middle income countries (LMC).

Feed price-quality relations

Animal nutritionists tend to focus on feed quality and feed nutrients but often neglect feed costs. However, both

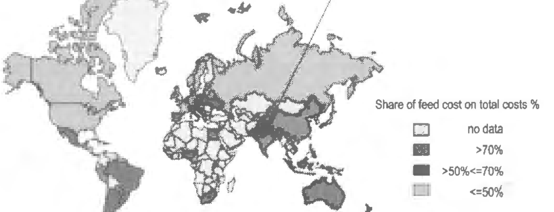

Fig. 1. Share of feed costs in total costs of dairy production (Modified from Hemme *et al.*, 2011).

[1]National Dairy Development Board, Anand, India
[2]International Livestock Research Institute, Nairobi-00100, Kenya

types of information are needed, that is feed value and feed price, to make economically rational decisions about ration design and feeding. Singh *et al.* (2016) surveyed 65 commercial dairy compound feeds in six districts in Bihar during 2015 for price – quality relationships. Quality traits were crude protein, neutral (NDF) and acid detergent fiber (ADF), acid detergent lignin (ADL), crude fat, *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME). Price per kg feed concentrate ranged from Rs. 12 to 30 with a mean of Rs. 17. Table 1 shows the multiple regression between feed price and feed quality traits selected by the model when offered all quality traits.

Table 1. Variations in prices in 65 compound and concentrate feeds accounted for by laboratory feed quality traits

Feed quality trait	Partial R^2	Total R^2	$P < F$
ME	0.155	0.155	0.001
Crude protein	0.076	0.231	0.02

Source: Singh *et al.* (2016).

Key messages:

Increasing feed costs need to be checked and the trend that feed costs rise faster than farm gate prices for ASF need to be at least arrested but preferably reversed and to that animal nutrition can contribute through three major pathways:

- Always combine feed quality and feed cost information through regular monitoring by an independent body.
- Decrease cost per unit feed nutrients for example for protein and energy.
- Increase ASF production per unit feed nutrients.

Only CP and ME were selected, accounting together for 23% of the variation in feed costs, leaving 77% of the variation in feed costs unaccounted for. Using ME content to calculate how much it would cost to produce an additional litre of milk the feed cost could vary from Rs. 10.3 to 24.5 (mean Rs. 14.8). Put differently, feed value and feed price in commercial concentrates were not closely associated. There are likely to be major reasons for that: insufficient attention was paid to nutrient-price proportions and problems with feed quality control and certification. In fact, livestock producers in LMCs that lack effective implementation of feed quality monitoring and certification control complain about insufficient quality in purchased compound feeds. For that reason, some larger livestock producers built their own small scale feed plants, in order to better control quality.

Key messages:

Increasing feed costs need to be checked and the trend that feed costs rise faster than farm gate prices for ASF need to be at least arrested but preferably reversed and to that animal nutrition can contribute through three major pathways:

- Always combine feed quality and feed cost information through regular monitoring by an independent body
- Decrease cost per unit feed nutrients for example for protein and energy
- Increase ASF production per unit feed nutrients

Increase feed resources from forages and crop residues: breeding

Feed scarcity is very likely the major factor for feed costs increasing faster than farm gate prices for ASF. The National Institute for Animal Nutrition and Physiology (NIANP) estimated the deficit in feed energy and protein as more than 50% while the feed dry matter deficit was estimated at below 10% (NIANP, 2012) (Feed deficit here relates to feed resources required to fill an existing yield gap). To animal nutritionists the primary challenge is therefore to rise feed quality rather than feed quantity. Key entry points reside in collaborations between animal nutritionists and forage and crop breeders. Forage breeders have favoured forage yield over forage quality for a long time, resulting in forage cultivars with excellent biomass yield but digestibilities often around, and below, 50%. Crop breeders on the other hand neglected crop residue quantity and quality until very recently altogether (Blümmel *et al.*, 2017). Table 2 shows the forage yield and quality of a the new quickly becoming popular perennial forage sorghum CoFS 29 over a year using two different water management regimes.

Thus, while forage yields of CoFS 29 per cut and accumulatively in the course of a year are excellent and can make a real contribution to increasing fodder availability. The average forage nitrogen content was 2.0 which could still be considered somewhat aligned with expectations but the average IVOMD of below 50% has certainly to be considered very poor for a green forage (see below).

That substantial variations in fodder quality in perennial green forages exits was demonstrated in collaboration between animal nutritionists and the ILRI forage gene bank. Gene mining work was applied to make new selections of Napier or Elephant grass (*Cenchrus*

Table 2. Means and ranges in fresh and dry forage yields and forage nitrogen (N) and *in vitro* organic matter digestibility (IVOMD) of CoFS 29 grown under bore and waste water irrigation 2015 to 2016 in Patancheru, Telangana (Seven cuts in a 12-month period).

Trait	Bore water		Waste water	
	Mean	Range	Mean	Range
Forage fresh yield (kg/ha/cut)	34 126	15 157-61 283	32 807	26 012-51 575
Forage dry yield (kg/ha/cut)	5 951	2 242-9 500	5 480	3 834-8 428
Total forage fresh yield (kg/ha)	477 770		459 293	
Total forage dry yield (kg/ha)	83 318		76 726	
Forage N (%)	2.00	1.55-2.22	2.02	1.54-2.43
Forage IVOMD (%)	49.1	42.3-53.4	49.4	43.1-53.4

purpureus) by marker assisted selection with the ultimate aim to develop new varieties by marker assisted breeding. Like CoFS 29 the grass is well recognised for its rapid regeneration and production potential, with reports of DM yields of up to 85 t/ha/year when well-fertilised. Research to date has identified high producing lines with good agronomic qualities and huge variations in key forage quality traits (Table 3).

Table 3. Forage quality traits variations in 84 forage gene bank accessions of Napier

Trait	Mean	Range	
		Leaf	Stem
Crude protein (%)	16.5	5.9 to 23.6	6.4 to 20. 9
IVOMD (%)	62.1	53.7 to 68.0	54.1 to 73.0
ME (MJ/kg DM)	8.6	7.8 to 9.7	7.8 to 10.4

Crop residues present the bulk of feed resources in India (Ramachandra *et al.*, 2007) and recently crop improvement started to consider crop residue fodder traits in their selection and breeding programs. International and national crop improvement institutions in India in collaboration with animal nutritionists from ILRI were spearheading this paradigm change in crop improvement. Fig. 2 outlines the rationale behind this and the improvement that can be made in crop residue fodder quality when crop breeders and animal nutritionist co-operate. The sorghum data in Fig. 2 were derived from a survey of sorghum stover trading in Hyderabad in 2005 to 2006 (Blümmel and Rao, 2006). Over the course of a year, stover from 6 different cultivars were traded and there were price premiums for higher quality stover. A difference of 5% units (range 47 to 52%) in IVOMD was associated with a price premium of about 25%. The sorghum stover fodder market survey influenced CIMMYT maize improvement that had realized that sorghum substitution by maize needs to consider maize stover fodder traits since sorghum stover provides a major part of the livestock feed in rain-fed India. CIMMYT and ILRI co-operated in a maize program with maize stover fodder quality improvement as a major objective. This program generated maize hybrids maintaining high grain yields (still the primary trait) but with average stover IVOMDs surpassing even the best of the traded sorghum stover (Fig. 2).

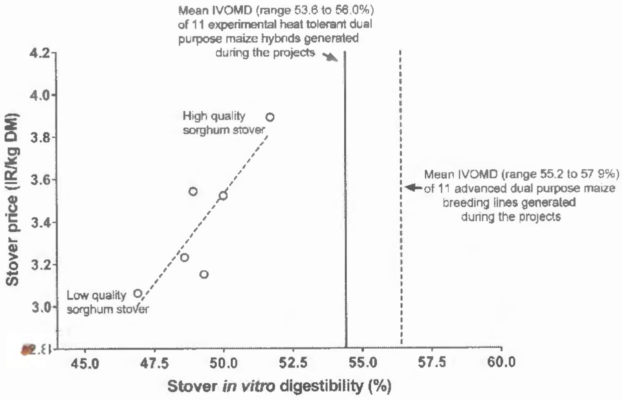

Fig. 2. Breeding advance in dual purpose maize stover fodder quality relative to different sorghum stover traded in rainfed India in the past decade (Blümmel *et al.*, 2014a).

The findings in Fig. 2 should also be compared with the forage data presented in the Table 2 above: if cereal crops can be bred with average IVOMDs in their stover residues after full grain maturity of >50%, it is difficult to accept that forages are bred with average IVOMDs of below 50%.

Key messages:

Feed biomass can be significantly improved by co-operation of plant improvement and animal nutrition where the latter needs to:

- Promote the importance of feed biomass fodder quality in addition to quantity.
- Advise on suitable laboratory feed quality traits.
- Facilitate phenotyping for feed quality by generating quick and affordable laboratory infrastructure such as Near Infrared Spectroscopy.
- Support ex-ante assessment of the impact of improved forage and crop residue feed quality on animal performance.

Increase feed resources from forages and crop residues: leveraging technologies for deconstruction of ligno-cellulose complexes

The work on second generation bio-fuels (bio-fuels derived from lignocellulosic biomass) has potentially provided useful technologies to animal nutritionists for the deconstruction of ligno-cellulose complexes in crop residues and forages. This paper presents findings from three 2[nd] generation biofuel technologies applied to upgrading the fodder quality of a wide range of Indian cereal straws and stovers: 1) steam treatment, 2) ammonia fiber expansion (AFEX); and 3) IICT 2-Chemical combination treatment (2CCT).

Table 4. Summary of effects of steam, ammonia fiber expansion and 2CCT treatment on *in vitro* gas production (GP) and true *in vitro* digestibility† after 48h of incubation.

Spin-off technology	n	*In vitro* GP-48h (ml/200 mg)		True IVOMD-48h (%)	
		Untreated	Treated	Untreated	Treated
Steam treatment	4	48.6	53.6	62.9	71.8
AFEX treatment	10	42.9	51.5	65.1	84.4
2CC treatment	11	39.7	66.7	55.9	94.1

†The average difference between true and apparent IVOMD is about 12.9 percentage units (Van Soest, 1994). Increments in digestibility are similar independent of expression as apparent or true digestibility.

On an average, the two-chemical combination treatment (2CCT) increased true IVOMD by 38.2 percentage units from 55.9 in untreated straws and stovers to 94.1% after treatment. Such an increase is amazing and converts the straws and stovers in essence into (energy) concentrate feeds. The true IVOMD measurement is gravimetric in nature and calculated from the truly undegraded residue; all substrate not recovered is supposed to have been digested. This might not always be the case particularly in treated feed stuffs where some undigestible substrate might have been solubilized and so not recovered in the incubation residue. However, the increase in true IVOMD of 68% agrees with the average increase *in vitro* GP of 66% (66.7 vs 39.7 ml) and GP reflects the generation of fermentation products and is so not gravimetric in nature. Put differently, the increases in straw and stover quality seem to be real.

Steam treatment and 2CCT were further tested with sheep fed total mixed rations containing about 70% of untreated, steam treated and 2CCT treated rice straw. The TMRs were iso-nitrogenous (about 12.6% CP). Figure 3 reports voluntary feed intake and accumulating weight gain in sheep fed three TMRs.

The spin-off technologies 2CCT and steam treatment increased weight gain in rice straw based TMRs 3.7 and 2.4 times compared to the TMR containing untreated rice straw. The effect of steam treatment on voluntary feed intake is dramatic resulting in a DMI of more than 5% of live weight in male sheep (when expressed as OMI more than 4% of body weight). For impact of AFEX treatment on animal performance see the work done at NDRI by Mor *et al.* (2018).

Key messages:

The work on 2[nd] generation bio-fuels has attracted US multi-billion dollars of investment during the last two decades. It is feasible for animal nutritionists to leverage spin-off technologies from these investments to upgrade lignocellulosic biomass for animal feeding.

- Pre-treatment spin-off technologies of biomass up to the generation of glucose (or equivalents) are interesting, from here on rumen microbes and mammalian enzymes can take over
- Spin-off technologies already exist that can convert crop residues into (energy) concentrates
- Spin-off technologies need to be adapted by use of small and medium feed enterprises (see also Chapter below)
- Need and opportunities for animal nutritionists to leverage technologies from advanced life sciences given the reduced funding for the classical animal science disciplines

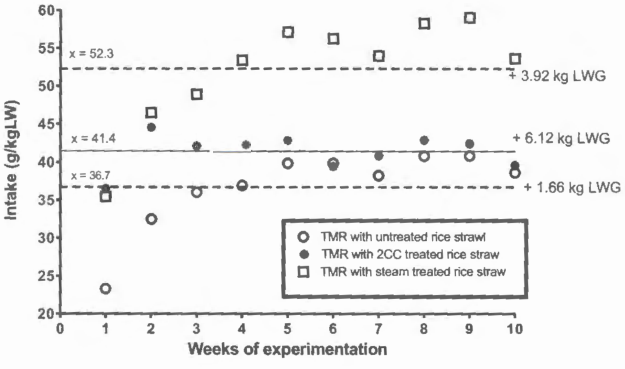

Fig. 3. Response of sheep fed total mixed rations containing 70% of untreated, 2CCT treated and steam treated rice straw (Blümmel *et al.*, unpublished).

Matching and optimizing feed nutrient supply and animal performance on-farm

Feeding of dairy animals in LMC is often opportunistic and feeding consists typically of one or two locally available feed ingredients, supplemented with green fodder/grasses and crop residues. This often leads to imbalanced feeding which means critical nutrients like protein, energy, minerals and vitamins are either more or less when compared to nutrient requirement. A balanced ration provides all essential nutrients to the animal in such proportions and amounts that are required for the proper nourishment of animals in 24 hours (Garg *et al.*, 2013). It would provide protein, energy, minerals and vitamins from dry fodders, green fodders, concentrates, mineral supplements etc., in appropriate quantities to keep the animal in its form to perform best with respect to production and health. While imbalanced feeding adversely affects the health and productivity of animals in various ways, it also reduces the net daily income of milk producers as the milk production potential of animals is not fully exploited. As mentioned before, the need for improving the nutrition of dairy animals is absolutely crucial when feed costs account for more than 70 per cent of the total cost of milk production.

In a comprehensive approach to apply animal nutrition principals to improve on farm feeding, a user-friendly ration balancing programme (RBP) has been developed by the National Dairy Development Board (NDDB) for creating least cost balanced ration at the milk producer's homestead, using locally available feed resources and area specific mineral mixtures (Garg *et al.*, 2014). On feeding balanced ration, it is possible to improve milk production efficiency and net daily income of milk producers in an environmentally sustainable manner (Garg *et al.*, 2015). Along with the ration balancing advisory services, milk producers also need to be educated on other relevant aspects of scientific animal rearing and feeding practices. In the World Bank funded project National Dairy Plan-I (NDP-I), more than 2.7 million dairy animals in 40,000 villages in India were covered under RBP under the umbrella of NDDB. For programme implementation, the technical manpower of end-implementing agencies (EIAs) were trained at NDDB who in turn imparted training to local resource persons (LRPs). With the help of hand-held devices loaded with the software, trained LRPs provided ration balancing advisory services to dairy farmers. Each animal covered under RBP was identified with a unique ear tag number enabling entire data monitoring. While the project has ended, RBP is still implemented in more than 30,000 villages in different parts of India. Table 5 summarizes the key impact of RBP on the economics of dairy production, animal health and the environment.

Key messages:

Ration balancing programs have significant effect on the efficiency of feed utilization, the economics of dairy production and the environmental footprint of ASF production

Table 5. Summary of key dairy productivity variables after application of ration balancing approaches in India[†].

Impact on	Cows (n=1.74 million)		Buffalo (n=1.05 million)	
	Mean	Range	Mean	Range
Milk production (kg/d)	+0.85 (±0.02)	0.40-3.10	+0.42 (±0.01)	0.15-2.20
Milk fat (% units)	+0.3 (±0.01)	0.1-1.5	+0.3 (±0.03)	0.1-1.8
Feed costs[‡] (Rs/kg milk)	-1.8 (±0.21)	0.5-3.5	-1.1 (±0.01)	0.4-3.2
Daily feed costs (Rs/d)	-25 (±2)	15-40	-25 (±2)	10-35
Milk efficiency (kg FCM/kg DMI)	+0.2	0.58 to 0.78	+0.13	0.53 to 0.66
Reduction in CH_4 (%/kg milk)	-18	11-24	-16	10-20

[†]Average daily milk yield in cattle and buffalo before RBP was 9.1 kg (7.9 to 15.6 kg) and 7.8 kg (5.6 to 11.4 kg) respectively.
[‡]In animals yielding 8 to 10 kg milk per day.

- Major effects appear to be on reducing feed costs and increasing feed efficiency rather than increasing milk production
- For a small holder having 5 dairy animals average daily benefit would be around 125 Rs
- Increased feed efficiency reduced GHG foot print (see also following Chapter)

Feed resourcing and feeding and environmental foot prints

Feed resourcing and water requirement

Water required to produce feed to satisfy maintenance energy requirements for one Tropical Livestock Unit is about 100 times greater than the water required for drinking (Peden *et al.*, 2007). In regions with strong competition for land and water resources, land and water scarcity emerge as major constraints for increased feed production in small-holder systems. For example, in Northern India, water-use efficiency was found to be low in systems with high reliance on irrigated forages (Singh *et al.* 2004). Singh and colleagues reported for Gujarat that on average 3 400 liters of water were required to produce one liter of milk - the world average is 900 liter. Expressed differently, about 10,000 liters of water were required daily to produce the feed for one dairy animal (Singh *et al.*, 2004). Clearly water requirement needs to be of concern to those who work in feed resource development and animal nutrition. Based on the feed supply-demand tool (Feed Base) developed by the National Institute of Animal Nutrition and Physiology, a conceptual model was constructed that combined feed supply scenarios with the water requirement to produce it (Blümmel *et al.*, 2014b). Water requirement is calculated from rainfall and reference evapotranspiration (ET_0) or detailed climatic parameters to compute ET_0. Many countries have a good density of climatic station network that, with relatively straightforward processing, can provide the necessary input data. This model allows animal nutritionists to calculate livestock-water productivity on a given feeding regime and the amount of water required per unit ASF (Blümmel *et al.*, 2014b). Feed resource strategies can thus be designed that optimize water use per unit ASF produced. For example, crop residues based total mixed rations TMRs (see also further below) that can reduce water requirement per kg of milk by half to 1643 liter under current crop yield and to 548 liter when a crop yield gap of 1:3 was closed (Blümmel *et al.*, 2014b).

Ration design, feeding and greenhouse gas emissions

Besides high water requirement greenhouse gas emissions (GHG)remain a major concern, though the initial assumptions of Steinfeld *et al.* (2006) were shown to be misguided and an exaggeration (Mitloehner, 2018). Considerable efforts have been expended in reducing carbon emissions from livestock, even before the awareness of climate change took hold, simply because feed carbon losses to the environment reduce feed conversion efficiency. The mechanisms that result in enteric carbon emissions are, therefore, quite well understood. In a simplified manner, digestion in the rumen is characterized by feed conversion into short chain fatty acids (SCFA), the 2-, 3- and 4-carbon acids, acetate, propionate and butyrate which provide the primary energy source for ruminants, microbial biomass (MBP) which is the major or even only source of protein and finally the gases, mainly CO_2 and CH_4 which are digestive waste products and obviously of major environmental concern. Since diversion of feed carbon away from gaseous losses has livestock nutritional and environmental benefits, considerable research has been invested in devising feeding strategies that achieve this, and our knowledge about the underlying causes is expansive (Van Soest, 1994). Briefly, high proportional feed conversion into MBP, that is a high efficiency of microbial production (EMP), and high proportion of propionate in the SCFA, reduce digestive carbon losses (see Fig. 4).

Clearly, increasing proportional propionate production will have the most substantial effect on methane emissions relative to feed digested. While under feeding regimes which promote predominantly acetate-based fermentation, methane emissions could range from about 45 to 70 liters per kg digested feed depending on EMP, only about 20 to 30 liters of methane are produced when propionate dominates fermentation products (Fig. 4). In other words, methane emissions could be halved by adjusting the feeding regime. From a mere feed technical perspective, high propionate production can be "simply" achieved by increasing the proportion of concentrate in the diets. In fact, this approach is frequently recommended

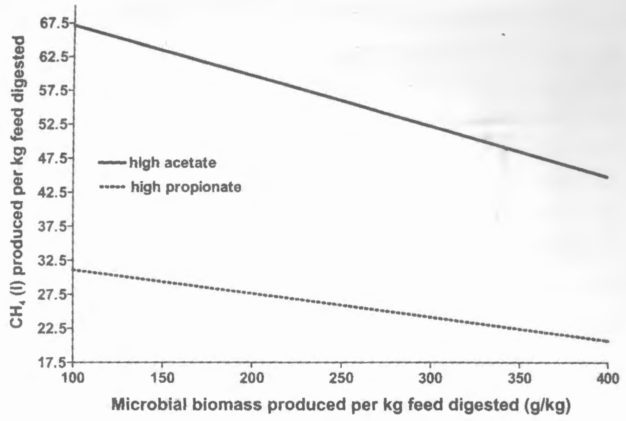

Fig. 4. Methane production from 1 kg of feed truly digested in the rumen in dependence of SCFA proportion and EMP (modified from Blümmel and Krishna, 2003).

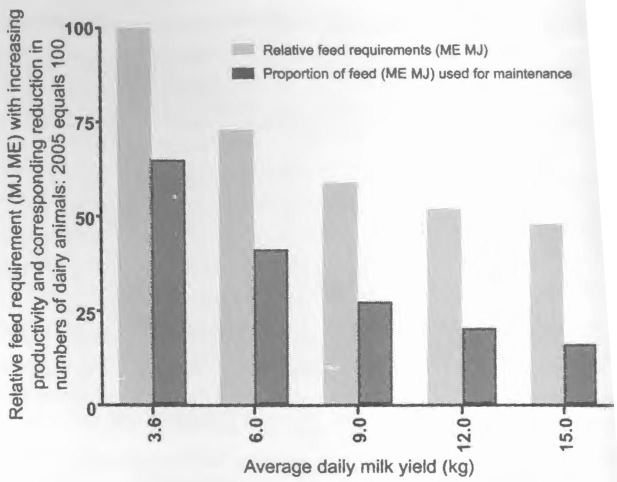

Fig. 5. Feed requirement in dependency of per dairy animal productivity: the Indian scenario (calculated from Blümmel *et al.*, 2013)

for reduction of methane emissions from livestock (for review see Martin *et al.*, 2008). There are, however, severe draw backs associated with increased concentrate feeding to ruminants, particularly in developing countries. First, food security might be in jeopardy and food prices might increase, further burdening poor people. Also, natural resource usage of land, water and biomass is more efficient where livestock production (mainly from ruminants but not only) is based on by-products such as crop residues that do not contain human edible nutrients or on biomass harvest - through grazing and otherwise - from areas not suitable for arable land.

Feed supported intensification and the impact on feed need and GHG

Low environmental footprint production of ASF demands that increased production be met by increased efficiency of production and not through increased animal numbers (Leng, 1993). Feeding strategies that increase the efficiency of production by producing more from fewer animals and less feed will result in reduced GHG. This can be demonstrated by analyzing the livestock population in India and their respective level of productivity. Thus, in India in 2005/2006 the proportion of dairy animals relative to total livestock numbers was less than 0.25. In addition, the daily milk yield of cross bred cows, local cows and buffalo was low, averaging on a 365-day lactation basis 6.44, 1.97 and 4.3 liters per day, respectively. The mixed herd mean milk yield can be calculated as 3.61 liters per day (Table 6).

By increasing daily milk production in a herd model (of a mixed crossbred, local cow, buffalo population) from 3.61 to 6, 9, 12 and 15 liter per day and assuming an aligned reduction in number of animals, energy expended for maintenance becomes less than energy expended for production, see Figure 5. In addition, total feed requirement (here in terms of ME) for the production of 82,000,000 million tons of milk is about halved.

The fact that the same amount of milk can be produced by less numbers of livestock would result in drastically reduced emissions of methane (see Figure 5 and 6 a/b adapted from Blümmel *et al.* 2013).

Key messages:

Improving feed efficiencies goes hand in hand with reduced environmental foot prints of ASF production

- Animal nutritionists can design rations with a high conversion of feed carbon into useful fermentation products and reduced losses as CH_4 and CO_2
- Shifting proportional feed use from maintenance to production is a strategy for intensification
- Feed supported intensification with accompanying decrease in number of animals will decrease overall feed need for a unit of ASF produced and its environmental footprint

Labour requirement and drudgery involved in feed resourcing and feeding

Feed sourcing, transport and feeding are among the major users of labor in livestock production. This is particularly the case in ruminants, given the need for large volumes of often low quality fodder material. And this is particularly true in smallholder production where low costs of labor mean that mechanising feed production, collection and feeding is not economically viable. In such systems, using manual approaches to feed activities is simply cheaper than expensive machinery which also requires

Table 6. Dairy animal and their production in India in 2005/2006: Total milk production about 82,000,000 tons

	Crossbred cows	Local cows	Buffalos	Total
Dairy animals	8 216 000	28 370 000	33 137 000	**69 759 000**
Milk yield (kg/d)	6.44	1.97	4.4	**3.6 (mean)**

Adopted from Blümmel *et al.* (2013).

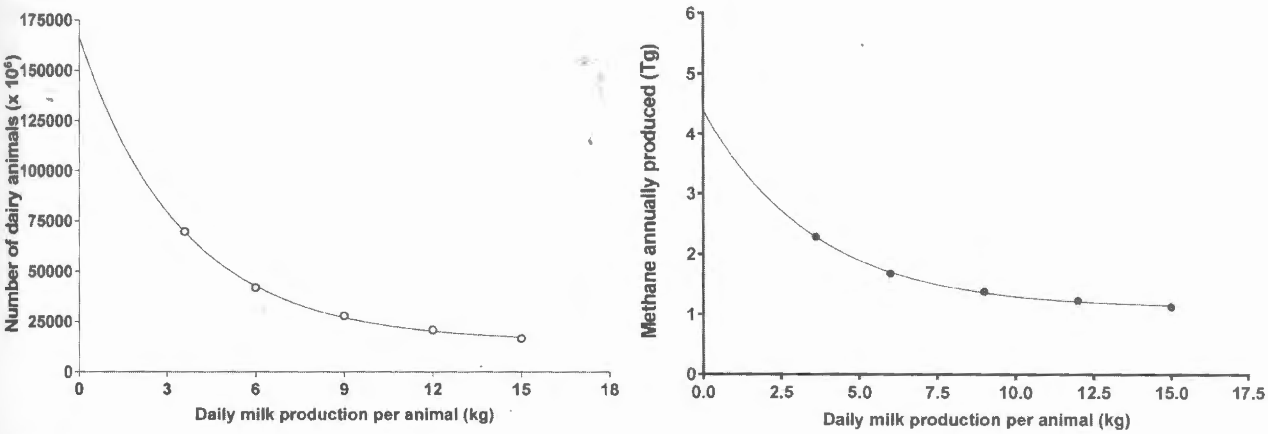

Fig. 6 a/b. Possible reduction in numbers of dairy animals with increasing per animal productivity and the impact on total methane production when the same amount of milk (about 82,000,000 million tons) is produced from fewer animals.

expert technicians to service, which are often not available in rural areas. In fact, making use of underutilized family labor, as well as making use of available crop residues and forages from communal properties, are the key factors that allow smallholder ruminant producers to compete economically with larger scale producers, who typically have to pay market rates for both labor and feeds. Nevertheless, there is an enormous amount of drudgery required in feed activities, particularly in smallholder dairy in land scarce settings for example, where large volumes of fodder have to be collected and transported on a daily basis because pastures are not available or inadequate. In many countries, women perform the bulk of this work, although they may be assisted through use of animal draft power or employees in the case of somewhat larger production units. In some such systems, employment on small livestock farms can be quite substantial. In highland Kenya, half of small dairy farms, which typically only have 2-3 cows, have full- time employees, and feed activities occupy the largest proportion of their time.

The accumulative effects of these factors is presented in Figure 7 (which is based on primary data collection from 164 households in Kenya) in form of a feed cost-benefit analysis. This survey conveys two important messages: the economic benefits from apparently similar feed technologies – here forage technologies can vary hugely – and labour costs are the single most important determinant of it.

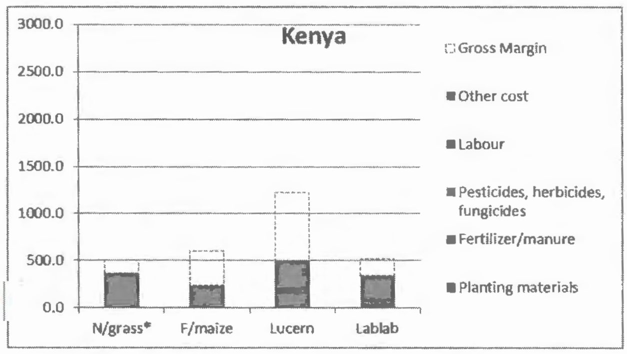

Fig. 7. Cost-benefit analysis of various feed technologies and the importance of labour cost.

Labor demand, particularly in dairy, is already very high specifically where scale of operation is low. Comparing 4 farm types in India (Farm 1: two dairy animals no land, Farm 2: four dairy animals 3.7 ha land, Farm 3: twenty-two dairy animals 4.8 ha of land and Farm 4: thirty-seven dairy animals and no land.

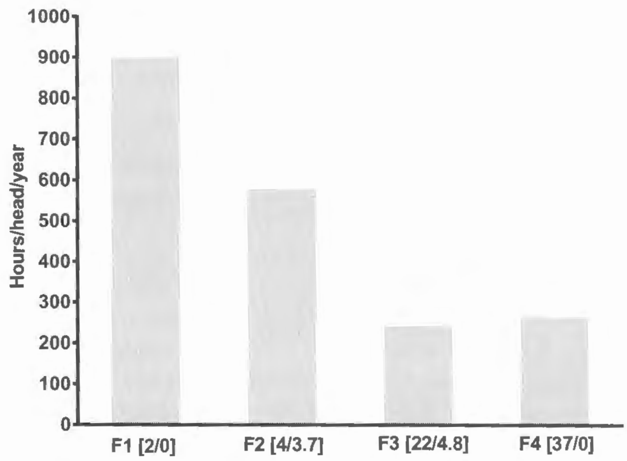

Fig. 8. Labour input per dairy animal on 4 farms in India with widely differing numbers of animals and land sizes (modified from Hemme *et al.*, 2003).

Key messages:

Labour is a key issue in animal husbandry and particularly feed resourcing and feeding that animal nutritionists need to consider on a high priority basis when exploring and promoting feed interventions

- Labour constraints are important drivers for the rising need for off-farm produced feed, also for small holders
- Labour costs are generally the most expensive input into on-farm feed technologies
- None- economical labour aspects of feed resourcing and feeding such as drudgery need to be considered, especially when placed on women and children

Besides the economic implications of labour demand in feed resourcing and feeding, labor needs to be considered even where its opportunity costs are low. Feed resourcing and feeding is often the task of women and children, inferring for example in the case of the latter with educational opportunities. Swaans (2015) has reported that changes in feeding practices – here disposing with cooking of feed – reduced labor requirements of women in Odisha project sites by 2 to 3 hours daily.

Opportunities for micro, small and medium enterprise (MSME) in feed production, marketing and processing

The impact of the RBP (Table 5) suggest that the impact of feed interventions that to a large degree depend on making better use of feed resources produced on-farm, are limited. Scarcity of land and water and increasingly labor, constrain the extent to which feed resources can be improved on farm. In other words, the demand for affordable off-farm produced feed is increasing and will very probably do so at an increasing rate in the years to come. This demand offers opportunities for micro, small, medium and large enterprises to become engaged in feed production, transaction and processing. In India for example Poshak Agrivet Pvt. Ltd. and Miracle Feed and Fodder Pvt. Ltd. designed total mixed rations consisting mostly of by-products as feed blocks with an air-dry weight of 15 kg. Miracle Fodder and Feeds Pvt. Ltd. (Shah, 2007) feed blocks for example consisted of sorghum stover (about 50%), bran, oilcakes, husks (about 36%) with the rest contributed by molasses (8%), maize grain, urea, minerals, vitamins etc.

Miracle Fodder and Feeds Pvt. Ltd. offered TMR feed blocks of three different qualities designed to produce daily (in dairy buffaloes) 11-16 liters (DTMR Diamond with 14.5 to 15% CP, 3.5% fat and 64-65% TDN), 7-11 liters (DTMR Gold with 13.0 to 13.5% CP, 3.0% fat and 62% TDN) and 5-7 liters (DTMR Silver with 11.5 to 12.0% CP, 2.5% fat and 60% TDN). Similarly, Poshak Agrivet Pvt. Ltd. offered TMRs of three different qualities. Both Poshak Agrivet Pvt. Ltd. and Miracle Feed and Fodder Pvt. Ltd. folded, respectively changed their business model from producing and selling TMR to producing and selling lower throughput machinery for TMR production.

The lesson to be learned is that very centralized and high throughput production systems do not work for ruminant feed production because huge amounts of high bulk-low density feed ingredients have to be transported over long distances with the finished produce possibly facing long transport distances as well. Decentralized business models are required. Animal nutritionists must contribute to such decentralized business models for example with feed price - feed quality-animal performance matrices like the one exemplified in Table 7 and 8. The four TMRs chosen from the old product lines of Poshak and Miracle Feed and Fodder present the range in ME available in the different TMRs. Decentralized new players in feed production like Fertile Green Inc. in Andhra Pradesh try the use of simplified ex-ante assessments that helps them in the design of new feed options like assessing potential feed costs as portions of farm gate revenues from ASF, here milk. Fertile Green Inc for example hold that a guiding principal for a cut-off point of what farmers are willing to invest in feed relative to the sales price of milk is about 60%. Incidentally the proportion of feed costs relative to sales process of milk in the data used in Table 5 was 67 and 50% for cattle and buffalo, respectively.

Total mixed ration production and marketing are certainly at the upper end of the scale of possible MSME engagement in feed production, processing and marketing. However, there are multiple entry points along the scale, from micro to medium enterprises. Swaans (2015), for example, reported successful engagement of farmer groups in the production of mineral supplements. Planting forages as-cash-crop is another enterprise that requires few resources and could therefore be very suitable for rural

Table 7. Feed cost (IRs/kg) for 4 different TMRs feed at a rate of 15 kg (air-dry) and 13.5 kg (dry) per day to dairy buffalos weighing 500 kg and assuming a farm gate price for buffalo milk of Rs. 44/kg and allowing feed costs relative to farm gate milk prices of 75, 70, 65, 60, 55 and 50%.

TMR	ME (MJ/kg)	Milk yield (kg/d)	75%	70%	65%	60%	55%	50%
			Price per kg TMR (Rs./kg)					
Miracle Feed and Fodder Diamond	9.74	10.7	23.6	22.0	20.4	18.8	17.3	15.7
Poshak VILAYATI BEHLI	9.06	9.2	20.3	18.9	17.6	16.2	14.9	13.5
Poshak DUDHARU BEHLI	7.85	6.6	14.5	13.5	12.6	11.6	10.6	9.7
Poshak JATAN BEHLI	6.79	4.4	9.7	9.1	8.4	7.8	7.1	6.5

Table 8. Income from feeding for 4 different TMRs feed at a rate of 15 kg (air-dry) and 13.5 kg (dry) per day to dairy using assumptions from Table 7

TMR	Cross milk income (Rs./d)	75%	70%	65%	60%	55%	50%
		Cross income minus feed costs (Rs./d)					
Miracle Feed and Fodder Diamond	471	117	141	165	189	211.5	235.5
Poshak VILAYATI BEHLI	405	100.5	121.5	141	162	181.5	202.5
Poshak DUDHARU BEHLI	290	72.5	87.5	101	116	131	144.5
Poshak JATAN BEHLI	194	48.5	57.5	68	77	87.5	96.5

disadvantaged population. For example, the CoFS 29 forage described in Table 2 is now planted on small pieces of land under irrigation and has a market value of about 2 IRs per kg fresh forage. The agricultural service sector providing ploughing, harvesting and threshing services can complement equipment and for example offer chopping and hay and silage making services. Animal nutritionists will play an important role here, since they can translate the various feed interventions into the production of ASF and the income from it - indispensable for the development of viable business plans.

Key messages:

Promising private sector engagement in making better use of by-products folded probably because the business set-up was too centralized, the economy of feeding insufficiently appreciated and the willingness of livestock producers to invest in purchased feed not sufficiently assessed. Despite these setbacks:

- Demand for affordable off-farm produced feed will very likely increase
- Animal nutritionists, economists and private sector need to co-operate in the development of viable business plans for feed production and for implementation of these business plans in a structured way
- TMR concept needs reconsideration, respectively adaption to context, in that separate processing and sale of the concentrate part should be considered, which can be supplemented to on/farm locally sourced straws and stover
- Micro and low investment enterprises in feed production and marketing are possible, opening employment opportunities for youths.

Conclusions

The discipline of animal nutrition has a key role to play in livestock based livelihoods to: a) increase the economic benefit from ASF production by decreasing feed costs and/or increasing ASF production, b) decrease the environmental footprint of ASF production, c) reduce labour requirements and drudgery involved in feed resourcing and feeding; and d) provide opportunities for micro, small and medium enterprises (MSME) in feed production, marketing and processing to generate income and employment opportunities and while increasing the availability of affordable off-farm produced feed. To achieve this, we need to give greater attention to working in partnerships with economists, socio-economists, plant improvement and natural resource management, other life sciences, development actors, policy makers and the private sector. Animal nutrition can well be the core of these partnerships, being at the interface where these diverse disciplines can be given a united purpose.

References

Blümmel, M. and Krishna, N. 2003. Evaluation of feedstuffs–alternative methods. In: *Feed Technologies: Present Status and Future Strategies*. Acharya NG Ranga Agricultural University, Hyderabad, India, pp. 67-74.

Blümmel, M. and Rao, O.P.P. 2006. Economic value of sorghum stover traded as fodder for urban and peri-urban dairy production in Hyderabad, India. *International Sorghum and Millets Newsletter,* 47: 97-101.

Blümmel, M., Homann-Kee Tui, S., Valbuena, D., Duncan, A. and Herrero, M. 2013. Biomass in crop-livestock systems in the context of the livestock revolution. *Secheresse,* 24: 330-339.

Blümmel, M., Zaidi, P.H., Vinayan, M.T., Babu, R. and Yadav O.P. 2014a. The fodder value of maize stover vis-à-vis other cereals residues and opportunities for improvement through crop breeding and value addition. In: *Maize for Food, Feed, Nutrition and Environmental Security* (Eds. B.M. Prasanna *et al.*), 30 October – 1 November, 2014, Bangkok, Thailand.

Blümmel, M., Haileslassie, A., Samireddypalle, A., Vadez, V. and Notenbaert, A. 2014b. Livestock water productivity: feed resourcing, feeding and coupled feed-water resource data bases. *Animal Production Science*, 54: 1584-1593.

Blûmmel, M., Muller, A., Schader, C., Herrero, M. and Garg, M.R. 2017. The use and abuse of cereals, legumes and crop residues in rations for dairy cattle. In: *Achieving Sustainable Production of Milk*, vol. 3. Burleigh Dodds Science Publishing Limited, Cambridge, UK, pp. 273-291.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. and Courbois, C. 1999. *Livestock to 2020: The next Food Revolution*. International Food Policy Research Institute, Food and Agriculture Organization of the United Nations, and International Livestock Research Institute. IFPRI Food, Agriculture and the Evironment Discussion Paper 28, Washington, DC, 72 p.

FAO. 2017. *Food Balance Sheets*. Food and Agriculture Organization of the United Nations.http://www.fao.org/economic/ess/fbs/en/

Gain Report 2017. *India: Dairy and Products Annual.* GAIN Report Number IN7123.

Garg, M.R., Sherasia P.L., Bhanderi, B.M., Phondba, B.T., Shelke S.K. and Makkar H.P.S. 2013. Effects of feeding nutritionally balanced rations on animal productivity, feed conversion efficiency, feed nitrogen use efficiency, rumen microbial protein supply, parasitic load, immunity and enteric methane emissions of milking animals under field conditions. *Animal Feed Science and Technology,* 179: 24-35.

Garg, M.R. and Sherasia P.L. 2015. Ration balancing: A practical approach for reducing methanogenesis in tropical feeding systems. In: *Climate Change Impacts on Livestock: Adaptation and Mitigation* (Eds. S. Veerasamy, J. Gaughan, B. Lance, C.S. Prasad), Springer, New Delhi, pp. 285-301.

Garg, M.R., Sherasia, P.L., Phondba, B.T. and Hossain, S.A. 2014. Effect of feeding a balanced ration on milk production, microbial nitrogen supply and methane emissions in field animals. *Animal Production Science,* 54: 1657-1661.

Hemme, T., Asaah, N. and Schröer-Merker, E. 2013. Overview on milk prices and production costs world-wide. International Farm Comparison Network Report.

Hemme, T., Garcia, O. and Saha, A. 2003. A review of milk production in India with particular emphasis on small scale producers. Pro-Poor Livestock Policy Initiative Working Paper No. 2.

Kristjanson, P. 2009. The role of livestock in poverty pathways. In: *Proceedings of Animal Nutrition Association World Conference*, February 14-17, 2009, New Delhi, India, pp. 37-40.

Leng, R.A. 1993. Quantitative ruminant nutrition - A green science. *Australian Journal of Agricultural Research*, 44: 363-80.

Martin, C., Doreau, M. and Morgavi, D.P. 2008. Methane mitigation in ruminants: from microbes to the animal.In: *Livestock and Global Climate Change*. Cambridge University Press, Cambridge, UK, pp. 130-133.

Mitloehner, F.M. 2018.Yes, eating meat affects the environment, but cows are not killing the climate. Sourced as ILRI CLIPPINGS BLOG: October 9, 2018.

Mor, P., Bals, B., Tyagi, A.K., Teymouri, F., Tyagi, N., Kumar, S., Bringi, V. and VandeHaar, M. 2018.Effect of ammonia fiber expansion on the available energy contentof wheat straw fed to lactating cattle and buffalo. *Indian Journal of Dairy Science*, 101: 1-14.

NIANP. 2012. *FeedBase*, National Institute for Animal Nutrition and Physiology, Bangalore, India, pp. 530–560.

Peden, D., Tadesse, D. and Misra, A.K. 2007. In: *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture* (Ed. D. Molden). International Water Management Institute, Colombo, Sri Lanka, pp. 485-515.

Ramachandra, K.S., Taneja, R.P., Sampath, K.T., Angadi, U.B. and Anandan, S. 2007. *Availability and Requirement of Feeds and Fodders in India*. Published by National Institute of Animal Nutrition and Physiology, Bangalore, India.

Shah, L. 2007. Delivering Nutrition. Power Point Presentation delivered at the CIGAR System Wide Livestock Program Meeting September17, 2007 at ICRISAT, Patancheru, India.

Singh, O.P., Sharma, A., Singh, R. and Shah, T. 2004. Virtual water trade in dairy economy. *Economic and Political Weekly*, 39: 3492-3497.

Singh, D.K., Swain, B.B., Ravi, D., Teufel, N. and Blümmel, M. 2016. Price – quality relationship in commercial dairy concentrate feeds in Bihar. In: *Innovative Approaches for Animal Feeding and Nutritional Research* (Eds. Chander Datt, Sachin Kumar, Goutam Mondal, Nitin Tyagi, S.S. Thakur, Mahu Mohini and Rakesh Kumar) Books of Abstracts of XVI Biennial Animal Nutrition Conference, February 6-8, 2016, Karnal, India, 344 pp.

Steinfeld, H., Gerber, P., Wassenaar, T., Castel V., Rosales, M. and De Haan, C. 2006. *Livestock's Long Shadow: Environmental Issues and Options*. Food and Agriculture Organization of the United Nations, Rome, Italy.

Swaans, K. 2015. A qualitative study on the uptake of residue-based feed technology among farmers in the state of Odisha and Bihar in India. ILRI Cereal Systems Initiative for South Asia (CSISA) Technical Report Commissioned by ILRI.

Van Soest, P.J. 1994. *The Nutritional Ecology of the Ruminant*, 2nd ed. Cornell University Press, Ithaca, NY, USA.