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Forage based feeding systems of dairy animals: issues, limitations and strategies

S.K. Mahanta[1]*, S.C. Garcia[2] and M.R. Islam[2]
[1]ICAR-Indian Grassland and Fodder Research Institute, Jhansi-284003, India
[2]Dairy Research Foundation, University of Sydney, Camden-2570, Australia
*Corresponding author e-mail: mahantask@rediffmail.com

Abstract

The key problem in high producing dairy animals with forage/pasture based diets is getting adequate net energy intake to meet the requirements of animals, besides methane emissions. Hence efforts should be made to improve the efficiency of feed utilization including energy and protein. Feed conversion ratios (FCR) of the energy and protein in feeds consumed by animals vary depending on species, production systems, feed type and products. Non-ruminants are most efficient on the basis of total food produced from total feed intake, but dairy cows and other ruminants return more human food per unit of human edible feed consumed because most of their feed resources are obtained from materials that cannot be consumed directly by humans. The values on human edible FCR for energy (0.15 to 0.93) and protein (0.07 to 0.71) were comparatively low in dairy cows of India than Australia, indicating relatively more use of human edible sources of feeds (cereal grains) in dairy cows of developed countries to maximize the production as well as profit. But keeping in view the food security at global level, efforts should be made to improve the human edible FCR so that a dairy cow can produce more edible milk energy or protein than it consumes as feed, which requires substitution of concentrate feeds/cereal grains by high quality forages.

Keywords: Australia, Dairy animals, Feeding systems, Forages/pastures, India

Introduction

Dairy animals are one of the man's most valuable and renewable resources. The dairy cows are indispensable utilizing marginal lands, crop residues and by-products inedible by humans. It is stated that the greater the effort to increase forages and pasture-fed animal products the more food for people and the better for the planet. While feeding grains to dairy animals and other ruminants has evoked an economical argument about the competition between human and animals for food (FAO, 2003; Godfray *et al*., 2010). Because most developed countries see dairy animals being fed grains, they erroneously assume that this occurs elsewhere, otherwise grains being consumed by the animals could be given to people. In developing countries most domestic animals including dairy animals exist on feedstuffs, not edible by human (Devendra and Leng, 2011). Grains are fed to animals only in developed countries when the cost of feed energy per unit is less for grains/concentrate feeds leading to maximization of production as well as profit. Although, about 50% of the photosynthetic energy in cereal and seed crops is in the straw and stover portions, inedible by humans but edible by cows and other herbivores (Van Soest, 1994).

The ability of dairy animals and other ruminants to covert feed resources such as grassland/pastures and agro-industrial by-products into edible animal food of high biological value is likely to get greater significance in terms of global human food production as the population of the planet increases in future decades. Globally there are 3.4 billion ha of grazing and only 1.5 billion ha of cropping land (FAOSTAT, 2008). At global level, even today the food security is a burning issue as the number of malnourished people estimated to be around one billion (World Bank, 2008; WHO, 2019), despite the fact that world could produce enough food for its current population. But we have to improve the efficiency of utilization of those fibrous feed resources (Reid *et al*., 1980; Reynolds *et al*., 2011). The challenge is that a ruminant like dairy animal evolved 40 million years ago with a pregastric (rumen) digestion system to enable them to feed on forages, with methane produced as by-product and there is no advantage per se to that ecosystem of avoiding methane production (Gill *et al*., 2010). Accordingly, Godfray *et al*. (2010) concluded that although production and efficiency of feed use can be increased, but instead of maximising production, optimisation of production was a more appropriate strategy to pursue. Cereal grains are fed to dairy cows because production is much more efficient overall with higher energy diets. But dairy cows also convert their feed to high quality human food relatively efficiently; as being ruminant animals with always more than half of their diet consisting of forages and by-products, their return on human edible inputs typically exceeds 100%, *i.e.* the quantity of human food produced as outputs is greater than that of human edible inputs (Bradford, 1999).

This paper discusses the major issues in relation to present dairying and sustenance/ improvement of productivity in dairy animals fed forage based diets in India vis-à-vis Australia. Since majority of dairy animals both in India and Australia are raised on forage based diets with limited supplementation of concentrates (agro-industrial by-products) and cereal grains, respectively. However, poor quality cereal straws and stovers form the major source of forages in India, while it is good quality pastures/ herbages in Australia.

Characteristics of dairy animals

Dairy animals with their unique digestive tract, having four stomach compartments viz. rumen, reticulum, omasum and abomasum, they have pre-gastric fermentative digestion of feeds and forages in their rumen which is a microbiological vat with millions of bacteria, protozoa and fungi (Morgavi *et al*., 2010). These microbial rumen symbionts, which have co-evolved with their animal hosts for millions of years, are highly specific and perform metabolic functions that are essential for the development, health and nutrition of the animal. Thus enable them to efficiently use cellulose-rich forages, and cows are not obligated competitor with human for vital quality food resources. They are capable of grow, support themselves and efficiently produce just consuming only forages inedible for human being and for most of monogastric animals. In fact, natural feed habits of cows and other ruminants are grasser and/or brusher, but never grainer. They eat grains when they do not have available grasses or brushes or in man-made systems. Dairy cows maintained only on forages with or without feedstuffs inedible for human being, do have an infinite (renewable) and high quality human edible food conversion efficiency (Sal, 2011). A negative aspect is, however, the production of methane (a green house gas) in the rumen.

Dairy production systems

Majority of dairy animals in India are raised as a part of mixed farming systems. Mixed farming systems are considered most sustainable because of complementarities between crop and animal production activities. Animals derive most of their feed–fodder requirements from agricultural crop residues and by-products, and in turn provide draught power and dung manure for cropping activities. Animal production systems can broadly be classified as mixed rainfed, mixed irrigated, grassland/ pasture and landless/industrial (Thornton *et al*., 2003). In India mixed rainfed system is practiced on 46% of land and mixed irrigated system on 37% of land. Grassland and industrial systems are limited to 4 and 13% of land, respectively. However, mixed crop–animal systems are characterized by considerable heterogeneity in terms of species, production efficiency, management practices and commercialization. This heterogeneity was found in 15 crop–animal production systems, cattle or buffalo being the second or third largest economic activity in most of the systems (Birthal *et al*., 2006). But mixed farming systems are undergoing a steady change due to increasing pressure on animals to produce more to meet the growing food demand. The non-food contributions of animals like draught services and manure production are declining in importance because of increasing use of bio-mechanical inputs in crop production. Thus the interactions between crop and animal production are likely to be weakening, making the way for commercial production systems based on high-producing animals and external inputs. The commercialization trends are already visible in dairying.

In Australia the dairy animals are raised mainly on pasture based feeding systems. Australian dairy farmers are found to practice one of the following five main feeding systems on their farm (Dairy Australia, 2010)-

- System 1: pasture + other forages + low grain/ concentrate feeding in bail (*grazed pasture + other forages + up to 1.0 tonne grain/concentrates fed in bail)*
- System 2: pasture + other forages + moderate-high grain/concentrate feeding in bail *(grazed pasture + other forages + more than 1.0 tonne grain/concentrates fed in bail)*
- System 3: pasture + partial mixed ration ± grain/ concentrate feeding in bail *(pasture grazed for most or all of year + partial mixed ration on feed pad ± grain/ concentrates fed in bail)*
- System 4: hybrid system *(pasture grazed for less than nine months per year + partial mixed ration on feed pad ± grain/concentrates fed in bail)*
- System 5: TMR system *(zero grazing. cows housed and fed total mixed ration)*

However, feeding on pastures along with other forages and moderate to high grain supplementation (system 2) was found to be predominant (Fig 1). But the choice of a feeding system by a famer depends on farm's natural resources, the climate, the extent to which he prefers to focus on pasture or cows, labour constraints, and employment, technology and machinery preferences etc.

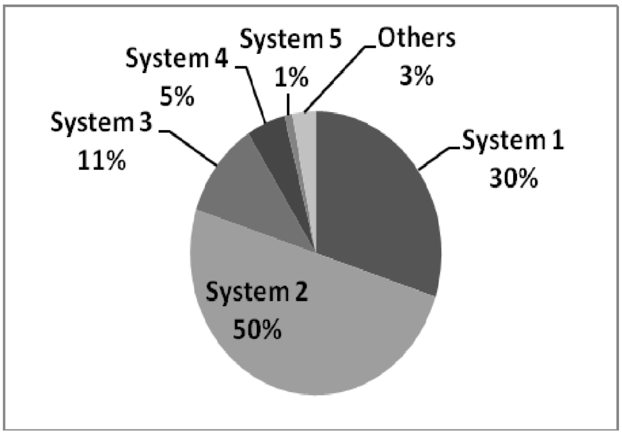

Fig 1. Proportion of Australian dairy farmers using different feeding systems

Feeding grains to dairy animals

In the year 2020, India is going to produce around 295 million tons of food grains but not more than 3.0% of total grain produced, is expected to be diverted for livestock feeding which also includes non-ruminant animals. Since India also have 1380 million people to feed them. Hence, due to pressure on cereal grains for meeting the demand of ever increasing human population coupled with high cost, it is difficult to use them for dairy farming in developing countries like India. Even among the food grains, coarse grains occupy the primary position. The production of coarse grains such as maize, sorghum, bajra and other millets around 48 million tons of which not more than 10% is presently used for livestock feeding. However, cereal by-products such as brans and polish and different oil seed meals including groundnut cake, mustard cake, coconut cake, soybean meal, cotton seed meal and sesame cake amount to around 16-20 million tons (Durge *et al*., 2017), while various agro-by-products, unconventional products such as molasses, distillery waste, wastes and by-products from meat, milk and fish, chiefly meat scrap, whey powder and fish meal are also put into use for livestock feeding. Thus total concentrate ingredients availability is around 45 to 47 million tons and the dairy animals are still raised on crop residues along with supplementation of those agricultural by-products (Planning Commission, 2007).

Australia is also expected to produce around 43 million tons of cereal grains this year, of which around 40% are expected to be diverted for livestock production. This is possible since Australia has only 25.5 million people. In more recent times growth in dairy farming as well as beef feedlot has been dependent upon accessing feed grains to support more intensive feeding and production. Having access to cereal grains has provided the livestock industries with a raw material source which is successfully value added to produce milk and meat. The dairy and beef feed use is now representing over 50% of total feed grain usage (Fig 2).

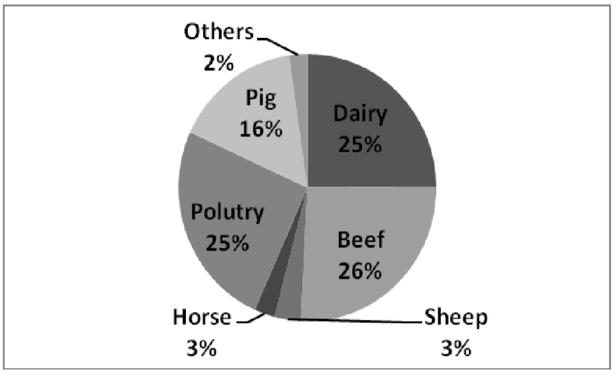

Fig 2. Grains used by different categories livestock in Australia (Spragg, 2008)

Milk production growth has occurred even though the dairy herd has remained relatively static at below 2.0 million numbers of cows. The milk production per cow has increased over the years and in part this is due to increased grain feeding. Grain and concentrate feed use has increased from around 800 kg/lactation in the early 1990's to now exceed 1700 kg/lactation. It is estimated by Dairy Australia that around 30% of Australian milk production comes directly from the feeding of grain. Thus it can be seen that a significant portion of the industry's growth in milk production and dairy exports over the last 15-20 year period has been the result of adoption of higher levels of grain feeding by dairy farmers (Spragg, 2008). In fact, grain feeding has now become an essential component in dairy farming systems, this being due to-

- Less reliable pasture production due to droughts and limited irrigation water availability
- Increased intensification with larger herds,
- Higher cost of land for expansion of pasture production
- Installation of automatic feeding systems
- Availability of grain and feed suppliers
- Influence of nutritional consultants
- Confidence in grain feeding economics relative to milk prices

Feeding forages to dairy animals

Forages are coarse bulky feed with high in fibre contents and low in digestible nutrients such as protein and energy. Historically, cattle lived on forages during most of the year with some concentrates during limited periods. Thus they are well adapted to utilization of forage nutrients to meet their nutritional needs. Cattle even require a substantial amount of fibre for good health and optimum performance (Stokes, 2002). Although there are other sources, most of the fibre consumed by cattle comes from forages. In addition to fibre, cattle obtain large amounts energy, protein, minerals, vitamins, lipid and water from forages. Usually forages are the most economical source of nutrients (Stone, 2011; Esmail.2020; Panhans *et al.,* 2020), especially energy but the cost relationship varies enormously in different areas, times and individual situations.

The common practice of feeding Indian dairy animals is to feed them on crop residues with little supplementation of green forages and concentrate feeds, but concentrates feeding results in increased cost of feeding. Feeding green forages, however, reduces the cost and has the potential of higher level of milk production. Nearly 65% of the total expenditure of milk production in cattle was attributed to the feeding of animals when both concentrates and green fodders were fed as mixed ration. But when the milk production depend upon concentrate based feeding, the cost of feeding towards milk production was 83%, while on forage based feeding, it could be reduced to only 40% of the total expenditure (Mahanta and Pachauri, 1999). Indeed, a dairy animal requires good quality forages (which have many additional benefits) for expression of full genetic potential of milk production. In Indian tropical climate, feeding of leguminous fodder like green berseem (*Trifolium alexandrinum*) or lucerne (*Medicago sativa*) and cowpea (*Vigna unguiculata*) during winter and summer/rainy seasons, respectively along with 1-2 kg of cereal straws to lactating cows and buffaloes sustained a milk yield upto 10 kg/day (Table 1). But animals yielding more than 10 kg/day required supplementation of energy rich concentrates @ 1 kg for every 2.5-3.0 kg of extra milk. Feeding of leguminous fodder exclusively resulted in wastage of protein/nitrogen (Voelker Linton and Allen, 2008), the most deficient nutrient in cereal fodder/crop residue based feeding regime. But a mixture of leguminous and cereal fodder at the ratio of 2:1 or 1:1 was found to be more promising. Cereal forages like maize (*Zea mays*)/sorghum (*Sorghum bicolour*) can be grown along with legumes like cowpea during rainy, and berseem & oat (*Avena sativa*) during winter season to supply a balanced fodder mixture. Cows consuming fodder mixture containing one part of berseem and oat each (fresh weight basis) with 1 kg concentrate (for letting down of milk) yielded 7-8 kg of milk/head/day. Similarly hybrid napier and lucerne (3:1) or maize and cowpea (1:1) mixture sustained upto 7 kg milk/head/day. Thus the intake and utilization of nutrients from comparatively low quality fodder were improved by judicious inclusion of legumes. Cereal fodders including grasses are poor in quality, having low protein and high fibre contents coupled with low voluntary intake. Therefore, performance of dairy animals fed on such fodders like maize, sorghum, guinea and hybrid napier grass etc. alone, were adversely affected which could meet only the maintenance with little production needs of animals. But supplementation of concentrates improved the level of milk production. However, oat at early stage of growth (upto 10% flowering) sustained 6-8 kg milk yield daily (Mahanta *et al*., 2009).

Milk production in Australia is based on use of grazed pasture/herbages, since perennial pasture is the cheapest source of feed on most dairy farms (Fulkerson and Doyle, 2001). However, there is wide variation betw-

Table 1. Performance of Indian dairy animals fed all forage/ forage based rations

Kind of forage*	Level of supplementation (head/ d)	Milk yield sustained (kg/d)
Berseem	1-2 kg cereal straws	8-10
Berseem	Concentrate @ 1 kg/ 2.5-3.0 kg extra milk	> 10
Cowpea	1-2 kg cereal straws	6-8
Hybrid napier + lucerne (3:1)	1-2 kg cereal straws	6-7
Maize + cowpea (1:1)	1-2 kg cereal straws	6-7
Berseem + oat (1:1)	1-2 kg cereal straws	7-8
Oat (10% flowering)	1-2 kg cereal straws	7-8
Berseem/ lucerne hay	1 kg barley grain	> 10
Cowpea hay (at 50% flowering)	1 kg barley grain	8-10

*Offered *ad libitum*; Source: Mahanta *et al*. (2009)

-een and within regions in the proportion of milk produced from pasture (Rawnsley *et al*., 2007; Thorrold and Doyle, 2007). Milk production from pasture was found to vary from 3,800 to 16,600 L milk/ha (Farina, 2010). A good ryegrass pasture was reported to produce 20 to 22L of milk per cow per day, which assumed normal genetic merit and no live weight change of stock and an acceptable level of pasture utilization. Production of up to 28L a day was also achieved with energy-based concentrates, which were fed to improve the protein to carbohydrate ratio of the total ration. In Tasmania well managed dairy farms were reported to produce of 20L of milk per day over the whole lactation from pasture and pasture silage. In Western Australia, top herds produced 28 to 30L per cow per day, of which 18 to 20L is estimated to come from pasture and the rest from approximately 5kg of concentrates a day. Above this level of production the situation becomes more complex and the nutrient composition becomes critical. Higher production can be obtained from pure swards of clover, but then the system becomes unstable. While kikuyu pasture was found of lower quality than ryegrass and sustained daily yields of 15 L of milk per cow without any change in body weight (Fulkerson *et al*., 1997). Although, Kolver and Muller (1998) reported that high yielding dairy cows in early lactation can produce upto 30L milk per day on quality pasture alone. But the body conditions of these animals decreased markedly during 4 weeks experimental period, indicating that such levels of milk yield cannot be maintained for long term. Moreover, excess mobilization of body reserves to sustain such high level of milk yield may lead to health and reproductive problems in high yielding dairy animals (Roche *et al*., 2000).

Limitations of forage based diets

Earlier it was also observed that dairy animals producing up to 23 kg daily milk can obtain nutritional support for production from excellent pasture alone and there was little benefit from feeding concentrate to animals grazing excellent-quality pasture, provided milk production was relatively low and forage dry matter digestibility remained above 70% (Donker *et al*., 1968). However, in high producing dairy cows, the key problem with high forage/ pasture based feeding is in getting sufficient net energy intake to meet the needs of a cow (Mertens, 2009). Common ways in which energy deficiency can be overcome are increased forage digestibility, increased efficiency of utilizing digested nutrients, increased forage intake, or increased supplementation with concentrates without a comparable decrease in intake of net energy from forage. Again feeding more energy than required for a cow to attain maximum potential production will not cause an increase in milk production, but normally will tend to increase body fat deposition. In fact, fattening begins before maximum milk production is attained. So if we foresee the possibility of much greater dependency on maximum forage/ pasture for high-producing cows, we must be quite concerned with how to increase net energy intake from forages/herbages. It is well known that growing better strains, varieties, or species and harvesting at less-mature stages gives greater digestibility and higher voluntary intake. But there are many situations in which these approaches have their own limitations (Miller and O'Dell, 1969). High yielding Holstein Friesian cows could not achieve their production potential by grazing pasture alone (Kolver and Muller, 1998; Kolver *et al*., 2002) or even when they were supplemented with grains (Bargo *et al*., 2002). Thus without considering the performance level of dairy cows, it can easily be concluded that the maximum forage in dairy rations could be 100%. However, 100% forage rations do not maximize productivity nor do they often maximize profitability or efficiency. Milk production results in a high energy demand, but rumen fill often limits the ability of cows to meet their genetic disposition to produce milk (Mertens, 2009).

Usually in high producing dairy animals, the forages are fed to meet all known nutrient requirements including energy and grains are fed to supplement energy for maximum milk production as well as net profit. But with higher proportion of grain feeding the key nutritional problem in high-producing animals appears to be how to maintain normal metabolism and health (Ostergaard and Grohn, 2000; Maekawa *et al*., 2002). There are many metabolic changes when cows are fed particularly high proportions of grains as compared to those fed larger proportions of forages and needs proper attention (Reis and Combs, 2000; Kocak and Ekiz, 2006). These changes occur in the rumen, including diminished rumination, alterations in microbial populations, a decreased acetate to propionate ratio, reduced rumen pH and, under some conditions, very high levels of lactic acid. The lowered acetate to propionate ratio is associated with reduced fat content of milk, and changes in the fatty acid composition of milk and blood. The reduced rumen acetate to propionate ratio is also associated with an increased rate of fat deposition and decreased energetic efficiency for body fat synthesis. Sometimes animals going off-feed, increased bloat, founder (laminitis), liver abscesses, rumen parakeratosis, gastric impaction, depraved appetite, constipation, diarrhoea, increased incidences of displaced abomasum, and possibly other indications of enterotoxaemia were also observed in cows fed grain based diets for a long time. However, when clinical lameness/laminitis occurs due to persisted acidosis in the rumen, reduction in feed intake and milk yields developed weeks or months earlier (Ostergaard and Sorensen, 1998). So even in high producing dairy animals, grains/concentrates should not be more than 50 to 60% of total dry matter of the diets which provides maximum energy intake (Wangsness and Muller, 1981). While earlier Kesler and Spahr (1964) concluded that there is no need to go beyond 50 to 55% grain in the diets because of depressed milk fat test, more off-fed problems, other metabolic upsets and impaired ability to mobilize body tissue reserves to supplement dietary energy. However, milk yield response to concentrates fed to dairy cows in a total mixed ration was linear up to the maximum level of 70% of total dry matter intake, without any adverse affect on milk fat content (Ferries *et al.*, 1999). This indicated the need for further studies on the interactions between feeding systems and rumen activities in dairy cows (Garcia and Fulkerson, 2005).

In contrary, if good quality forage becomes available like afalfa hay which could be harvested early to have higher contents of energy and protein with higher intake and net absorption of amino acids in relation to protein content of forage, then there is possibility of higher energy intake leading to higher milk production even on exclusive forage diets (Sniffen and Jacobson, 1975). A diet containing 40% poor quality late cut forage and 60% grain resulted in similar energy intake as a diet containing 100% high quality early cut forage (Tyrell and Moe, 1975), which showed the importance of early harvest as it relates to forage quality and energy of the total diet. The net result of feeding high quality forage was higher milk production. It was also observed that milk yield per day was higher for pre-bloom, high quality wheat silage than for mature silage at any level of grain feeding. Hence, detrimental effects of low quality forage cannot be substituted by grain feeding ((Wangsness and Muller, 1981). However, dairy cows in their early lactation fed alfalfa hay at three different stages of maturity (early vegetative, late bud and full bloom) with similar level of fibres in rations, but varying level of concentrates had no effect on milk production, milk composition or body weight changes (Kaiser and Combs, 1989). This indicated that there were differences in ruminal utilization of fibres from legume and cereal forages. Later it was concluded by Mertens (2009) that in a typical dairy ration, the forage-concentrate ratio should vary between 40:60 and 60:40. Within these boundaries high producing dairy cows need rations with ratios closer to 40:60 and higher quality forages allow ratios to be closer to 60:40.

Moreover, it is now established fact that feeding forage based diets gives rise to more CH_4 (g/kg of dry matter intake), a potent greenhouse gas (GHG), when compared to feeding grain based diets (Johnson and Johnson, 1995). Since starch present in the grains, promotes propionate production in the rumen and lowers ruminal pH, which inhibits the growth of rumen methanogenesis. Rumen protozoal numbers are also often lower in animals fed high grain diets, which also decreases the transfer of hydrogen from protozoa to methanogens. Consequently, there is considerable debate as to whether intensification of ruminant production (i.e., feeding higher grain diets, decreased grazing/forages) increases or decreases net farm GHG emissions (Mills *et al.*, 2003; Avery and Avery, 2008). Comparing whole farm GHG inventories for dairy farms in California, Wisconsin and New Zealand, where forages made up 43, 61 and 96% of diet dry matter, respectively, it was observed that total farm GHG emissions increased with forage proportion (Johnson *et al.*, 2002). This is in agreement with the findings of dairy farms in Ireland with dairy cows at varying levels of milk production potential (Lovett *et al.*, 2006). However, those studies did not consider that methanogenesis from manure can increase with grain feeding (Hindrichsen *et al.*, 2006), nor did they account for carbon sequestration in soil organic matter. If credit is given for the preservation of carbon in grazed pastures, dairy production systems based on forages often revert from being a net emitter to being a sink for CO_2 as compared to cropped land.

Again there is considerable variation in CH_4 production among forage types. CH_4 emissions per kilogram of dry matter intake were lower from ruminants fed legumes than from those consuming grass forages (Mc Caughey *et al.*, 1999; Waghorn *et al.*, 2002). CH_4 emissions were lower in cattle fed clover (losses of 7% gross energy intake) compared with perennial rye grass (8.5% gross energy intake) at similar levels of intake (Beever *et al.*, 1985) and this was associated with the rapid fermentation of plant cell contents in legume forages (Coulman *et al.*, 2000). Cultivated cereal forages like maize, sorghum etc contain significant quantities of starch, which favours production of propionate over acetate and reduces CH_4 production in the rumen. Moreover, intakes of those conserved cereal forages are often greater than that of grass forages. This reduces ruminal residence time and hence, restricts ruminal fermentation and promotes post-ruminal digestion. Cultivation of cereal forages, however, usually requires fertilization, harvest and preservation prior to feeding and these practices also contribute to GHG emissions through the burning of fossil fuels. With grazing of grass forages, these emissions are avoided and the opportunity for carbon sequestration in the soil is enhanced. These points illustrate the importance of using a life cycle approach in assessing the contribution of forages to total GHG emissions (McAllister *et al*., 2010).

Furthermore, advancing maturity of a forage with concomitant decrease in soluble carbohydrate content and increase in lignifications of plant cell walls, promotes the production of acetate and reduces the production of propionate in the rumen, thereby increasing the amount of CH_4 produced per unit of forage digested (Pinares-Patino *et al*., 2003; 2007). Higher enteric CH_4 emissions in cattle grazing alfalfa as compared to grass pastures was observed with this anomaly being attributed to the advanced maturity of the alfalfa (Chaves *et al*., 2006). However, because reductions in forage quality are frequently accompanied by a reduction in intake, it may be that the amount of CH_4 produced per unit of dry matter intake, or as a percentage of gross energy intake, is not influenced by forage quality (Pinares-Patino *et al*., 2003; Molano and Clark, 2008). Nonetheless, improvements in forage quality are believed to lower lifetime emissions or emissions per kilogram of milk or meat as a result of enhanced animal productivity (O'Mara *et al*., 2008).

In contrary, increased feeding of grains as a CH_4 mitigation strategy should be considered only after careful assessment using a life cycle analysis of dairy production system. In fact, the scope for using higher grain diets in dairy production in many areas of the world is limited because grain feeding ignores the importance of a dairy animal in converting fibrous feeds, unsuitable for human consumption, to high quality protein sources, and grains are becoming day by day more important for human sustenance (McAllister *et al*., 2010). According to Boehm (2011) a cow's production will keep increasing up to about 15,000 kg of milk per year, compared to, say, 5,000-7,500 kg in a forage system, but then the diet will be so high in grain that it will just be racing through her digestive system and efficiency starts to decline. At high grain levels we are really feeding the cow like a pig, which is really not how she was adapted over the years.

Strategies to improve milk production

Dairy farmers in a developing country like India have limited resources available for feeding to their animals. They often do not have the enough to even select the basal diet, they use whatever is available and at zero or low cost. The available resources are essentially low quality forages such as tropical pastures (both green and mature), straws and other crop residues and agricultural by-products which are generally low in protein. So the major criteria for improvement in production should be to optimize the efficiency of utilization of the available forage resource and not to attempt to maximize animal production. There is little point in knowing the requirements of nutrients of a lactating cow or buffalo, whose requirements are to be met from whatever crop residues are available. However, it is necessary to understand the requirements for supplements that will provide nutrients that will optimize the efficiency of utilization of those forage resources (Leng, 2011).

In contrary, in Australia high quality pastures are available which can support daily milk production of about 20 to 23 L with Holstein cows. Dairy cows will consume around 3% of the body weight as dry matter (DM) when fed only high quality pastures. Energy is the most limiting nutrient for dairy cows on pasture-based systems, and feeding supplemental grains to provide energy is profitable with typical relationship between milk and grain prices. In addition, grazing cows require more energy over maintenance than non-grazing cows because of higher levels of activity with walking. This may require about 1 to 2 kg of grains, which is a 'fixed' cost for activity without a return in milk production. The amount of grains fed to increase the total energy intake on a pasture-based system can have long term effects on energy balance, milk production, body weight and body condition changes, and reproductive performance. Moreover, there are changes in pasture composition and nutrient composition which make supplemental feeding with pasture-based systems more challenging than with confinement systems. We have less control over the forage component, both quality and quantity, with a grazing system, which reduces the consistency of nutrient intake from day to day. Cows graze several times per day, but may eat grains twice daily. However, if very high yields are expected from dairy cows, farmers will then have to move from simple grazing system to a more complex system in which animals are fed frequently on mixed diets of forages and grains. In Australia, this will lead to the loss of their greatest competitive advantage, to produce more milk at relatively lower costs in a pasture based system. Moreover, more complex feeding systems will not only affect the economic outcome, but also labour efficiency and lifestyle, pasture management and utilization, and animal welfare (Garcia and Fulkerson, 2005), thus requiring a whole farm context evaluation before adoptions.

But the key problem with supplemental feeding, whether it is India or Australia, is the non-availability of grains for feeding dairy animals in near future, since the prices for grains are likely to increase due to higher demand for biofuel production as well as growing demand for human consumption (Little, 2008; Godfray *et al*., 2010). So we will have to depend upon supplemental feeding of other feed resources to meet the nutrient requirements of a dairy animal for optimum milk production. Accordingly, efforts should be made to improve the efficiency of feed utilization in cereal crop residues (India) or pasture (Australia) based diets of dairy animals through supplementation of forages and concentrate feed by-products or even limited quantity of grains.

The most common expression of efficiency of feed utilization is the feed conversion ratio (FCR, kilogram of feed required to produce per kilogram of product, milk or meat). The proportion of feed energy/protein captured as milk and meat is inversely related to the amount of feed energy/protein that is not utilised and thus excreted. However, there are differences between a ruminant like dairy cow and non-ruminant in terms of the total dietary nutrient/energy available for metabolism and product synthesis. This is due to differences in the type of feeds they consumed and the physiology of the digestive tract and the associated digestive processes (Reid *et al.,* 1980). Thus when milk and meat production by cattle are compared to meat production by pigs or broiler, simple nutrient/energetic efficiency (amount consumed versus amount retained in product) in the ruminant is typically low due to their reliance on forages and fibrous crop residues as feeds and the role of fermentation in their digestion (Reynolds *et al*., 2011). In contrary, non-ruminants rely heavily on concentrate feeds like cereal grains and oilseed meals. However, the use of cereal grains by animals is causing concern, particularly in the context of a growing human population. Since the feed required to produce 1 kg of meat was 8, 4 and 1 kilogram of cereals per animal for cattle, pigs and broilers, respectively (Godfray *et al*., 2010). Although such comparison seems to be over-simplified and fails to take account of the extent to which different livestock systems have been developed to utilise land and feed resources that are not edible by the human population. The ability of dairy cows and other ruminant animals to turn feed resources such as grasslands, crop residues and other by-products from the agriculture and human food industry into edible animal food of high biological value is likely to become of greater significance in terms of global human food production as the population of the planet increases in future decades. Globally the conversion ratio of total feed to meat was 20: 1 and 3.8: 1 for ruminants and non-ruminants, respectively (Galloway *et al*., 2007). However, deducting feed inputs from crop residues and nonarable forages, the conversion of feeds from arable land to meat was 3: 1 and 3.4: 1 for ruminants and non-ruminants, respectively. Thus ruminants were observed more efficient than non-ruminants in terms of converting animal feed crops grown on arable land into meat (Wilkinson, 2011).

When FCR of total feed dry matter (DM) was compared among the production systems from different countries (Table 2), it was observed that FCR was around two times higher in Indian dairy animals than Australia or UK. But a higher value of FCR indicates a lower efficiency of feed into milk (Bradford, 1999). However, this higher FCR values in Indian cows or buffaloes, was attributed to feeding of low quality cereal crop residues with limited amount of concentrate feeds as well as their low genetic potentials. It was reported that only good quality concentrate feeds had the FCR of less than 1.0, that is, the output of liquid milk exceeded the concentrate feed input (Wilkinson, 2011). Total feed energy and feed protein conversion ratios were greater than total feed DM conversion ratios, indicating both feed energy and proteins are used relatively inefficiently to produce edible animal energy as well as protein in milk. The conversion ratios for energy in milk production, ranged from 3.63 to 6.65 MJ feed energy per MJ milk energy, which were around 2 to 4 times greater that the conversion ratios for total feed DM. Similarly the ratios for total feed protein conversion in milk production were much greater than the conversion ratios for total feed DM, indicating a very low overall efficiency of feed protein/ nitrogen into milk. This inefficiency in the conversion of feed protein into human edible milk protein is not only a source of diffuse pollution as nitrate and ammonia, but is also a potential source of greenhouse gas emissions as nitrous oxide in dairy productions (Wilkinson, 2011). However, the conversion ratios, either for total feed energy or protein into milk energy/ protein were lower in Indian dairy buffaloes, implicating relatively higher efficient use of available low quality feed resources into edible milk

Table 2. Comparative total and human-edible FCR (input per unit output) of milk in different dairy production systems

Dairy production systems	Total FCR			Human-edible FCR	
	DM (kg/ kg milk)	Energy (MJ/MJ milk energy)	Protein (kg/kg milk protein)	Energy (MJ/MJ milk energy)	Protein (kg/kg milk protein)
India (C)*	2.67	6.65	4.29	0.15	0.23
India (B)*	2.07	3.63	3.67	0.36	0.69
Australia (C)*	1.28	4.97	5.44	0.86	0.59
UK (C)**	1.10	4.50	5.60	0.47	0.71
USA (C)***	-	4.00	4.76	0.93	0.48
South Korea (C)***	-	3.85	5.26	0.27	0.07

FCR = Feed conversion ratio; DM = total feed dry matter; C = Cows; B = Buffaloes

*Estimated based on Wilkinson (2011); **Adopted from Wilkinson (2011); ***Adopted from Gill *et al*. (2010)

energy or protein than dairy cows of India or other countries. This was also attributed to higher energy as well as protein content in buffalo milk. In fact, this is one of the reasons for increasing buffalo population in past few decades in India (Birthal *et al*., 2006) and dairying is considered as pathways out of poverty (Randolph *et al*., 2007).

Different production systems, when compared in terms of total feed energy and feed protein efficiencies for milk production, in all the cases inputs exceeded outputs. In contrary, in terms of human edible return, outputs exceeded inputs for milk production, which suggested that dairy animals are mainly reared on feed resources like forages/ pastures and agro-industrial by products, having very low or zero human edible proportions and thus they are net contributors to human edible foods (Gill *et al*., 2010). The values on human edible FCR (Table 2) for energy and protein were comparatively low in dairy cows of India as well as South Korea than Australia, UK or USA. This indicated relatively more use of non-human edible sources of feeds (crop residues and forages) in dairy cows of India and South Korea. While dairy cows in developed countries like Australia, UK and USA were fed a good amount of concentrate feeds (cereals) of high human edible values to maximize the production as well as profit (CAST, 1999). So we should target to improve the human edible FCR so that a dairy cow can produce more edible milk energy or protein than it consumes as feed, which requires substitution of concentrate feeds/ cereal grains by high quality forages.

Conclusion

Thus, the challenge in forage based diets of dairy animals is to improve efficiency of feed resource use by matching available feeds to dairy animal requirements and at the same time reduce reliance on human edible feeds. Accordingly, a site-specific best practice in diet formulation and management of dairy animals may be adopted which will improve milk production efficiency as well as reduce methane emission. This will make dairy production sustainable, which implies the use of resources at rates that do not exceed the capacity to replace them.

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