Significance of feeding protected protein meals for improving efficiency of milk production in developing countries

M R Garg, B M Bhanderi, P L Sherasia, S K Gulati* and T W Scott*
Animal Nutrition & Feed Technology Laboratory,
Productivity Enhancement Group, National Dairy Development Board,
Anand 388 001 (Gujarat), India
* Faculty of Veterinary Science B 19, Sydney University, NSW 2006, Australia.

Most of the farmers in developing countries feed regionally available protein meals to their dairy animals, along with other ingredients. A significant part of these protein meals is broken down to ammonia in first stomach of ruminants; therefore, net availability of amino acids per unit of feed for growth and milk production is low. However, if these protein meals are processed optimally to reduce ruminal degradation and fed to dairy animals either using them as one of the ingredients of cattle feed/ concentrate mixture or as top feed, it is possible to increase daily milk production by 1.0 to 1.5 litres, per animal.

The National Dairy Development Board (NDDB) in India initiated research work on production of bypass protein feed by treating locally available protein meals, in technical collaboration with the Commonwealth Scientific and Industrial Organization (CSIRO)/Australian Centre for International Agricultural Research (ACIAR) and the University of Sydney, Australia, in the year 2000. Protected proteins were prepared by cross-linking the constituent protein with optimum levels of aldehyde, so as to enhance by about 75 per cent the level of constituent amino acids that by-pass the rumen. To achieve 75 per cent rumen protection, various protein meals like sunflower, rapeseed, groundnut and guar were treated with varying levels of aldehyde, so as to achieve a desired level of rumen protection.

Using treated protein meals, various feeding trials were conducted on lactating cows and buffaloes. Animals in all the feeding trials were divided in two similar groups, based on milk yield and stage of lactation. In addition, animals in control group were fed one kg untreated protein meal, whereas, animals in experimental group were fed one kg treated protein meal. Basal dry roughages fed in both the groups were similar depending upon the season and availability. Other feeding and management conditions were similar in both the groups. Daily feeding and milk yield in all the trial animals were recorded for a period of 10 weeks. Morning and evening milk samples were tested for protein and fat percent, on weekly basis. In all the feeding trials, daily milk yield in animals in experimental group increased by 1.0 to 1.5 litres, protein percent by 0.3 to 0.4 and fat by 0.2 percent, as compared to control group. On an average, daily net income per animal increased by Rs. 10-11 in experimental group, in comparison to control group, in animals yielding 8-12 litres milk per day.

Based on the findings of the feeding trials, a commercial bypass protein plant was set up in Baroda, in Western India, for producing 50 MT of bypass protein feed per day. Economic response of the bypass protein feed produced in this plant has been encouraging and the demand for this feed has been steadily increasing. Dairyboard plans to set up bypass protein plants in different parts of India, for treating and using locally available protein meals, with value addition, so that gap between demand and supply is minimized. Now, two more bypass protein plants of 50 MT per day capacity are being installed in the Western India. The technology can also be employed in other parts of the developing world.

Introduction

Internationally, about 1000 million-ton of animal feed is produced every year, including 600 million ton of compound feed (Gilbert, 2002). For manufacturing animal feeds, international trade of raw materials is the key to the global feed industry. Such raw materials are available from the local milling industry. The availability of protein meals is often essential for feed production. Following spread of the bovine spongiform encephalopathy (BSE) or mad cow disease, feeding of animal origin ingredients like bone meal, meat meal, blood meal etc., to ruminant animals have been banned by most of the countries, including India. The considerable and increasing demand for animal protein is focusing attention on alternative sources of feed protein and their suitability, quality and safety for future supply.

Alternative ways of meeting animal's protein requirement

Considerable efforts are being made to utilize more diverse local resources of feed ingredients, in particular protein meals, in many developing countries. In a country like Thailand, for poultry enterprises, there is a heavy demand of soybean and fishmeal. Greater utilization of indigenous feed materials is being encouraged for resource-poor smallholder and landless farmers for increasing ruminant production. For example, Wanapat (2002) has reported that there is considerable potential for cassava-based products in Thailand.

Sources of protein for animal feeds are many and varied, with considerable opportunities for further diversification and substitutions. Soybean meal, a residual product of the oil extraction from soybeans, is the most used and preferred protein source in animal feed, worldwide. This is due to its relatively high protein content of 45 to 50 percent. However, in India, cost of soybean meal is high compared to other protein meals, due to its great demand in the international market. Hence, soybean seeds and meals are exported from India, whenever, there is an opportunity. Mostly, soybean meal is used in poultry feed, it is used in ruminants feed, only when its cost is low in the domestic market. In addition to soybean, there are many other potential oil-seed meal crops to provide protein sources for ruminants i.e., palm kernel cake, the byproducts of oil palm production (e.g. in Malaysia and Indonesia). Oilseed rape is grown extensively in temperate regions (e.g. in Canada, European Union and Asia) and provides good protein meal.

Legumes are a traditional source of plant proteins for animal feed and their production can provide a range of benefits both on farms and for feed manufacturers. Peas, beans and lupins are exploited as grain crops in temperate farming systems and their production for homegrown protein supply is encouraged in the European Union.

Quality protein maize is grown widely in China and it has 13.5 percent protein and 100 per cent more lysine and tryptophan than normal maize (Vasal, 2002). Enhancing the value of major crops for animal feed use through genetic modification, utilizing modern biotechnological approach has been advocated by Hard (2002). Successful current examples of nutrient enrichment through genetic modifications include pro-vitamin A enriched rice, high lysine maize, high oleic acid soybean and low phytate maize.

Quality protein for ruminants can also be provided from various agro-industrial byproducts, like brewer's grain and maize gluten. Treating locally available protein meals is another option of increasing efficiency of protein utilization for growth and milk production. In India, feeding of protein meals with value addition is advocated to minimize the gap between availability and requirement (Garg et al., 2003; 2004).

Protein meals availability in India

Like most of the developing countries, there is shortage of protein supplements in India too. The farmers feed limited protein supplements available in the form of cakes/meals, to the milch animals without value addition. The total annual availability of protein meals in India is approximately 14.5 MMT, against a requirement of 40-45 MMT. Out of 14.5 MMT protein meals produced in the country, approximately 4.5 MMT are exported, which further increases the gap between the requirement and the availability (Table 1). This gap can be narrowed down, if the protein meals are used with value addition.

National Dairy Development Board (NDDB) has standardized a process in India, in collaboration with the Australian Centre for International Agricultural Research (ACIAR), the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the University of Sydney, Australia, by which protein meals can be utilized more efficiently in the system of ruminant animals. This can result in improved growth, wool and milk production. These protein meals are given suitable treatment and their degradation in the rumen is controlled, ensuring their improved net utilization for different production purposes, including milk (Garg, 1998; Garg *et al*., 2002, 2003). This technology is termed as "Bypass Protein Technology" and several scientists through out the world have shown its usefulness for the last more than two decades.

Advantages of bypass protein feed technology

- Higher availability of amino acids per unit of feed.
- Better utilization of those protein meals having higher rumen protein degradability.
- Judicious utilization of protein meals, available in limited quantity.
- Improves growth and milk production.
- Improves protein percent in milk, hence, improves SNF content of milk.
- Improves fat percent in milk.
- Better economic returns, for same input cost.
- Useful for low and high yielding animals, very relevant to Indian conditions of feeding and management.

Rumen microorganisms don't provide adequate protein for meeting the nutrient requirement of the lactating mammary gland for milk synthesis. Proteins, in ruminant diet are degraded to variable extent, depending upon their solubility and also the activity of rumen microorganisms. Protein degradation end products, such as ammonia, amino acids and peptides are utilized in turn by the microbes for synthesizing their own body proteins, depending upon the availability of carbon skeleton from the fermentation of carbohydrates. The amount of amino acids available for absorption in the small intestine is a total of that available from the microbial proteins and those proteins, which remain undegraded in the rumen but are subjected to enzymatic digestion in the lower digestive tract (Gulati et al., 2002). A schematic diagram of protein digestion in the ruminant animals is shown in Figure 1. In the process of microbial degradation, the biological value (BV) of high quality protein is often depleted.

Protein sources differ in their rumen degradability. Some protein meals contain naturally available rumen bypass protein (30 to 50 % of total CP) viz. cottonseed meal, toasted soybean, toasted groundnut meal, maize gluten etc., which can be used in bypass protein feeds. The cost of these ingredients is high, whereas, rapeseed meal, sunflower meal, guar meal etc. are available at cheaper rate but rumen protein by-pass content in these meals is low. Such protein meals having high rumen degradability can be subjected to heat or chemical treatment for increasing the level of rumen by-pass occurring.

In view of the high energy cost in developing countries and the potential to significantly increase the neutral detergent insoluble nitrogen (NDIN) and acid detergent insoluble nitrogen (ADIN) contents of heat treated protein meals, it is considered that aldehyde treatment of protein meals provides the most economically viable approach to optimize the RDP / UDP without significantly increasing the NDIN / ADIN. These by-pass protein meals can enhance the post ruminal supply of critical amino acids (Prasad and Reddy, 1998).

Protein meals treated with aldehyde in sealed chambers where these undergo formation of complexes, resist degradation in the rumen (Ashes et al., 1995). This closed system also ensures that the plant operator is not exposed to aldehyde vapor and the process occurs under occupational health and safety procedures (Owens *et al.* 1990; WHO, 2004). This attributes to HCHO-binding to the proteins by formation of methylene bridges (Fraenkel-Conrat and Olcott, 1948), which makes them resistant to microbial attack (Walker, 1964). Different protein meals could be tested for degree of protection using *in vitro* procedure to measure the degree of protection involved anaerobic incubations of replicates with treated and untreated meals together with pure proteins such as casein and blank tubes with strained rumen fluid from fasted donor sheep and / or steer; net rumen ammonia release was measured by steam distillation (Ashes et al. 1995, Gulat et al. 2002, Garg et al. 2004).

Treating protein meals with aldehyde has the following advantages:

- Desired level of protein protection can be achieved.
- Under and over protection of proteins can be eliminated.
- The bio-availability of the essential amino acids can be maximized.
- It does not increase the proportion of ADIN and NDIN contents.
- Less expensive.
- Also helps to control growth of salmonella and reduce mould growth in feed stuffs.

Initially, the technology of rumen protection of proteins relevant to Indian conditions was standardized by the NDDB by conducting various studies. Indigenous raw materials were evaluated for their rumen protein by-passability, using *in vitro* ammonia release technique. This test method gives reproducible results and is suitable for measuring protein by-passability of various raw materials (Table 2).

Optimization of treatment for protein meals

To avoid over or under protection, protein meals need to be given optimum chemical treatment, so that their digestion in the intestine can be maximized. To achieve approximately 75 per cent rumen protection in case of sunflower, rapeseed, groundnut and guar meals and different levels of aldehyde treatment was given. Maximum protection of protein meals was obtained at 9-10 days of incubation in airtight conditions (Figure 2). Raw materials enlisted in Table 2 were used for production of bypass protein and their effect was studied on lactating cows and buffaloes in various regions of India. Level of critical amino acids available for absorption in protected and unprotected protein meals are given in Table 3. Lysine and methionine are reported to be the most limiting amino acids for milk production (Schwab, 1995; Xu et al., 1998). On protection, availability of limiting amino acids increased significantly. Many feeding trials on bypass protein supplements (treated protein meals) were conducted on lactating cows and buffaloes.

Trials to study dose response of bypass protein meal in cows

Twenty crossbred lactating cows were divided into two groups of ten each, based on milk yield and stage of lactation. The control group was fed 0.5, 1.0 and 1.5 kg untreated sunflower meal successfully and similar quantity of treated sunflower meal was fed to the experimental group, each for a period of two weeks. Other feeding and management conditions were similar in both the groups. Daily feeding and milk yield in all the trial animals were recorded. Morning and evening milk samples were also tested for protein and fat percent, on weekly basis. Feeding one kg treated sunflower meal was found to be more economical, based on the results of daily milk yield, fat and protein per cent in milk.

Feeding trials with protected rapeseed meal

Twenty cows were divided into two equal groups of ten each based on milk production (average 8.5 litres) and stage of lactation. In addition to feeding practices being followed at the farm, animals in the control group were fed one kg untreated and in the experimental group one kg aldehyde treated rapeseed meal. Milk yield was recorded daily. However, fat and protein per cent of individual animals were recorded at weekly intervals. In the experimental group, milk yield increased by 1.1 kg per animal per day and fat and protein increased by 0.2 percent each, compared to the control group. Net daily income on feeding one kg treated rapeseed meal increased by Rs.8.80 per animal per day.

In another trial conducted on lactating cows using rapeseed meal, effect of aldehyde treated meal on milk and fat contents is shown in Figure 3. Increase in net daily gain in this trial was found to be Rs.8.40 per animal per day, almost similar to the above-mentioned trial.

Feeding trial with protected sunflower meal

A feeding trial on protected sunflower meals was conducted on milch cows. Twenty-four milch cows with an average milk yield of 10 kg were divided into two groups of ten each, based on the level of milk production and stage of lactation. Animals in the control group were fed 1.0 kg untreated sunflower meal, while, the animals in the experimental group fed 1.0 kg aldehyde treated sunflower meal. The increase in the milk, fat and protein content was 1.2 kg, 0.3 per cent and 0.2 per cent, respectively. Net daily income increased by Rs. 9.0 per animal.

Feeding trial on treated sunflower meal in lactating buffaloes

In India, buffaloes account for about 60 per cent of the total milk production. Moreover, buffalo milk has a much higher fat content, approximately 6-8 per cent as compared to 3.5-4.5 per cent for cows. Hence, a feeding trial on treated sunflower meal in lactating buffaloes was undertaken, to study economics of feeding treated protein meals in buffaloes.

Feeding trial using treated sunflower meal was conducted on 16 lactating buffaloes for 8 weeks. Buffaloes yielding 8-9 kg milk per animal per day were divided into two groups of eight each, based on milk yield, fat percentage and stage of lactation. The animals in both the groups were fed standard ration, comprising 12 kg green maize fodder and 5 kg paddy straw. Concentrate mixture was given according to their level of milk production. In addition to the basal ration, animals in control group were fed 1.0 kg untreated sunflower meal (Helianthus annuus; UDP 33 % of CP) and in experimental group 1.0 kg protected sunflower meal (UDP 75 % of CP). The daily average milk yield was 8.5 $\pm$ 0.15, 9.3 $\pm$ 0.14 kg, fat 6.7 $\pm$ 0.05 and 7.1 $\pm$ 0.06 % and protein 3.5 $\pm$ 0.01, 3.7 $\pm$ 0.02 % for the control and experimental groups, respectively. Average increase in milk yield (kg), fat and protein percent in experimental group was 0.80, 0.40 and 0.20 respectively. Increase in milk yield and fat percent in experimental group were significantly ($P<0.05$) higher, as compared to control group. However, no significant effect was observed on the level of protein percent in buffalo milk, unlike cow's milk. Average net daily income increased by Rs.14.49 on feeding 1.0 kg protected sunflower meal in lactating buffaloes. Significant effect of feeding treated protein meals milk production has been demonstrated by other workers as well (Hamilton et al., 1992; Garg, 1998; Gulati et al., 2002).

Feeding trial on treated guar meal

Guar meal is considered to be an important protein supplement, especially in Western India, having crude protein 48-50 per cent, with good amino acid profile. However, its rumen degradability has been found to be in the range of 68-70 per cent. In view of this, guar meal was treated to achieve 72-75 per cent rumen bypass protein and a feeding trial on this supplement was conducted on cows.

Twenty-two cows yielding 10-14 litres milk daily were divided in to two groups of 11 each, based on milk production and stage of lactation. All the animals in control group were fed 1 kg untreated guar meal daily, whereas animals in experimental group were fed treated guar meal @ 1 kg per animal per day. Daily milk yield, weekly fat and protein per cent were recorded for a period of eight weeks. Account of milk yield, fat and protein per cent of animals in both the groups are depicted in Figure 4. Daily milk yield in experimental group increased, by 0.9 kg per animal and fat and protein per cent increased by 0.2 per cent each. Net daily income increased by Rs.7.8 per animal on feeding treated guar meal, compared to untreated.

Bypass protein feeding trial on low yielding cows

In most of the developing countries, majority of milch animals daily milk yield is in the range of 4-5 litres, and these animals are mainly fed crop residues and small quantity of concentrate mixture as supplement. It is felt that the bypass protein supplement is meant only for high yielding animals. To assess the effect of feeding bypass protein on such animals, a feeding trial was conducted.

Sixteen crossbred cows yielding 4-5 litres of milk were divided in to two groups of eight each, based on 4% FCM. Animals in both the groups were fed similar basal ration, comprising 4-5 kg maize green and 5-6 kg paddy straw. Each animal in control group was fed daily 1 kg untreated rapeseed meal, whereas, each animal in experimental group was fed 1.0 kg treated rapeseed meal. Daily milk yield and weekly fat and protein per cent in milk of animals in both the groups were recorded up to 8 weeks.

Average daily milk yield increased by 0.7 kg in experimental group, in comparison to control. Similarly, fat and protein per cent in experimental group increased by 0.2 per cent unit each, compared to control group. Daily net income increased by approximately Rs.6.0 per animal in low yielding cows, on feeding 1 kg treated rapeseed meal, indicating economic advantage of feeding bypass protein feed in low yielding cows. This trial indicates that bypass protein feed is also economical for feeding low yielding animals.

Commercial production of bypass protein feed

Many feeding trials were conducted using different protein meals at various places in lactating cows and buffaloes. In all the feeding trials, daily milk yield in experimental group increased by 1.0 to 1.5 litres, protein percent by 0.3-0.4 and fat by 0.2 per cent. On an average, daily net income increased by Rs.10-11 per animal in medium yielding animals (8-10 litres per day) and Rs.5-6 per animal in low yielding animals (4-5 litres per day).

Based on the success of bypass protein feeding trials conducted on various categories of animals, a bypass protein plant (50 MT/day) was set up by NDDB at CFP, Itola, Baroda, Gujarat for treating protein meals on commercial scale and supply of bypass protein supplement to the farmers. Guar, rapeseed, groundnut and sunflower meals are treated in this plant and tested for protein bypassability in the laboratory, using *in vitro* ammonia release technique. The rumen bypassability in all these protein meals is approximately 75 per cent of crude protein (CP). These protein meals can be used in combination with other oilseed meals dependent on cost, and are generally used @ a 25 per cent inclusion rate in the compounded formulation, for producing bypass protein feed. Economic response of the bypass protein feed produced on this plant has been encouraging and the demand for this feed has been steadily increasing. Now, Dairyboard in the process of setting up more bypass protein plants for different parts of India, for treating locally available protein meals, so that net daily income from milch animals is increased and existing feed resources available in limited quantity are utilized more judiciously. The technology can also be employed in other parts of the developing world.

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Table 1. Indian oil meals production and export

Protein meal	Quantity ('000 MT)	
	Production	Exports
Soybean meal	5196	3650
Cottonseed meal	3296	1
Groundnut meal	1924	220
Sunflower meal	519	14
Rapeseed meal	2995	650
Sesame meal	226	1
Palm kernel meal	5	1
Copra meal	251	5
Linseed meal	131	--
Total	14543	4542
Source: Oil World Statistics Update: July 16, 2004		

Table 2. Levels of rumen undegradable protein (UDP) in various raw materials using cattle, buffalo or sheep rumen liquor

Protein meal	Crude protein (%)	UDP % of crude protein		
		Cattle	Buffalo	Sheep
Sunflower	31.52	33.40	33.78	33.81
Rapeseed	38.19	37.35	37.22	37.41
Guar	49.39	26.78	26.81	26.56
Soybean	45.76	37.81	37.67	37.55
Cottonseed	40.54	45.71	45.47	45.78
Groundnut	41.47	47.37	47.35	47.40
Source: Annual Report of Biotechnology Lab of NDDB, Anand, India, 2000-01				

Table 3. Level of essential amino acids available for absorption in unprotected and protected protein meals

Essential amino acids	Unprotected sunflower meal	Protected sunflower meal	Unprotected rapeseed meal	Protected rapeseed meal
Cysteine	0.73	1.84	1.95	3.71
Methionine	0.52	1.31	1.14	2.17
Isoleucine	1.33	3.32	2.90	5.50
Leucine	2.02	5.06	6.10	11.58
Phenylalanine	1.25	3.12	2.76	5.25
Lysine	1.14	2.85	4.12	7.82
Histidine	0.67	1.69	2.01	3.82
Arginine	2.34	5.85	4.26	8.09
Source: Indian Dairyman, 2002				

Figure 1. A schematic diagram of protein digestion in the ruminant animals

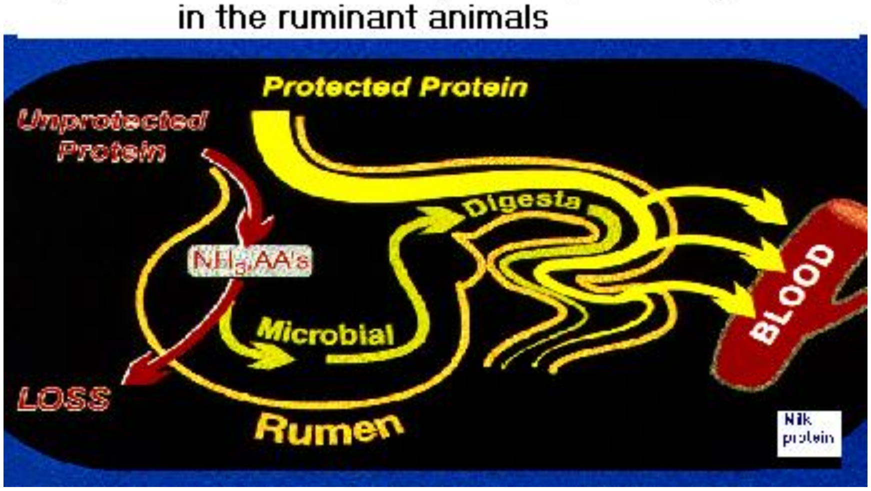

Figure 2. Degree of protein protection with days of incubation

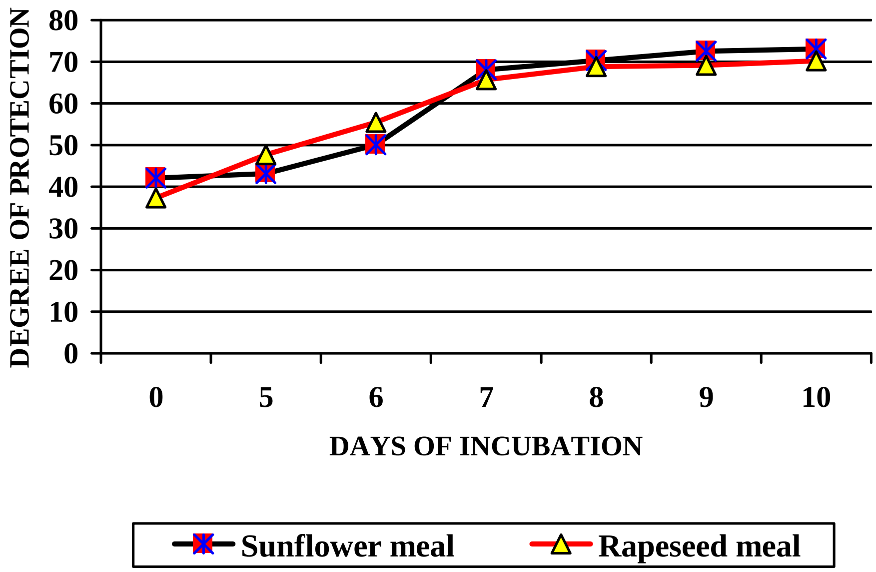

Figure 3. Effect of feeding 1.0 kg protected rapeseed meal in lactating cow

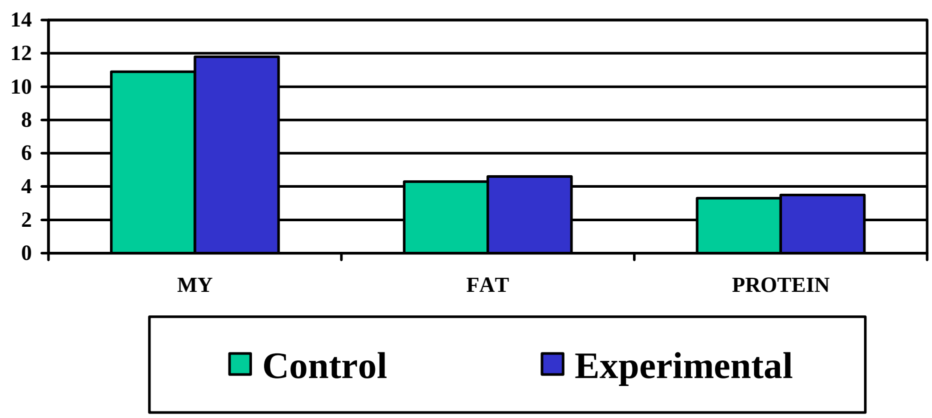

Figure 4. Effect of feeding 1.0 kg protected guar meal in lactating cows