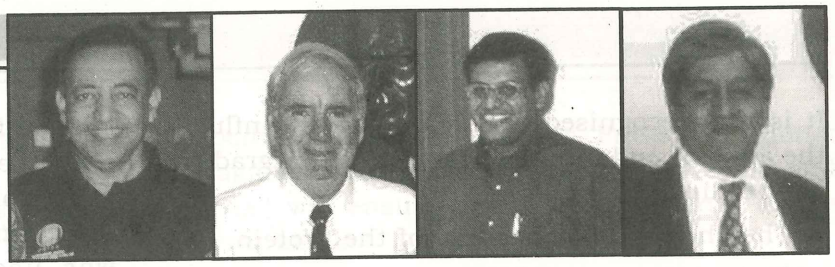
An Overview of Rumen Protected or By-pass Proteins and their Potential to Increase Milk Production in India[1]



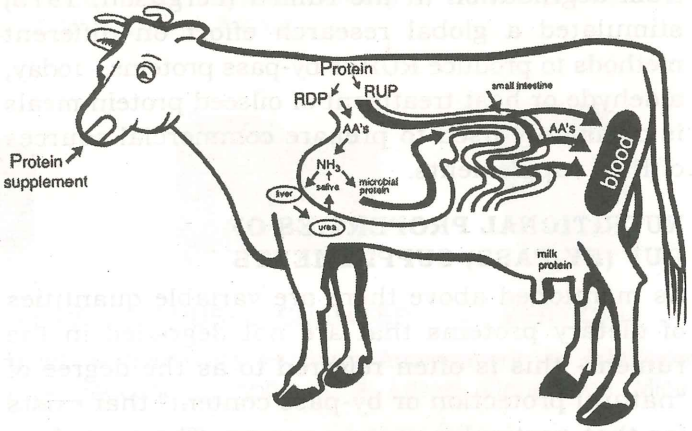
S.K. Gulati[2] T.W. Scott[3] M.R. Garg[4] D.K. Singh[5]

"Feeding optimally protected RUP supplement (1 and 1.5 kg per cow per day) significantly increased milk yield, fat and protein content. Economic analysis showed that feeding 1 kg of RUP supplement, compared to the naturally protected meal, produced the maximal net daily gain, being Rs 9:61 per cow per day."

HISTORY

Approximately 50 years ago the classical studies of McDonald and others (See Annison and Lewis, 1959) established the principles of protein metabolism in ruminants. They demonstrated that most of the dietary protein was rapidly degraded by rumen microorganisms; this is now commonly referred to as "Rumen Degradable Protein" (RDP). The end-products of rumen fermentation are amino acids, volatile fatty acids, ammonia, carbon dioxide and methane. This early research established the concepts of the "nitrogen cycle" - significant quantities of ammonia are produced in the rumen and some of this is used for microbial protein synthesis, the remainder is absorbed into the blood stream. In the liver, this ammonia is converted to urea and re-enters the rumen primarily *via* salivary secretions; here the microbes convert the urea to ammonia and carbon dioxide. In turn, this ammonia is used to sustain growth and multiplication of rumen microbes, which is essential for preserving the unique ecosystem and digestive processes of the ruminant animal. The continuous outflow of microbes to the small intestine, where they are digested, provides the host animal with sources of protein and constituent amino acids for milk, meat and fibre production. A small and variable amount of dietary protein escapes degradation, by-passes the rumen and is an important source of absorbable amino acids in the intestine, this is now called "Rumen Undegradable Protein" (RUP). The above processes are schematically shown in Figure 1.

Figure 1: A Schematic Diagram of Protein Metabolism in the Cow



1 Collaborative project supported by the Australian Centre for International Agricultural Research (ACIAR).

2 Project Leader (Protected Nutrients), Principal Research Scientist, CSIRO Livestock Industries, P O Box 136, North Ryde, NSW, 1670, Australia. Email: suresh.gulati@csiro.au

3 Ex-Chief, CSIRO, Animal Production and Consultant, ACIAR Project.

4 Senior Research Scientist, Research & Development Group, Animal Nutrition and Feed Technology. National Dairy Development Board (NDDB), Anand 388 001, Gujarat, India.

5 Senior General Manager (R & D), NDDB, Anand 388 001, Gujarat, India.

It is now recognised that many factors influence the amount and rate of dietary protein degradation in the rumen including:

- The chemical composition of the protein.
- The proportion of non-protein nitrogen (NPN) to true protein.
- The physical and chemical characteristics of the protein including its molecular structure and degree of cross-linking caused by chemical or heat treatment.
- The length of time the feed particles spend in the rumen.
- The proteolytic activity of rumen microbes.
- The amount of readily degradable carbohydrate to provide energy for microbial synthesis.
- The pH of the rumen environment.

Historically, much of the research effort concentrated on quantifying the amount of microbial protein that could be synthesised and how this was influenced by the levels of protein and energy in the diet. It became apparent that to satisfy the protein and essential amino acid requirements for milk, meat and fibre production there was a need to quantify the relative amounts of RDP/ RUP and in many circumstances increase the proportion of RUP in the diet. The early results using aldehyde to successfully protect proteins from degradation in the rumen (Ferguson, 1975) stimulated a global research effort on different methods to produce RUP or by-pass proteins - today, aldehyde or heat treatment of oilseed protein meals is commonly used to prepare commercial sources of RUP supplements.

NUTRITIONAL PROPERTIES OF RUP (BY-PASS) SUPPLEMENTS

As mentioned above there are variable quantities of dietary proteins that are not degraded in the rumen - this is often referred to as the degree of "natural protection or by-pass content" that exists for that particular protein source. The procedure commonly used to measure the by-pass content of protein meals is based on the nitrogen solubility in buffer solutions. This procedure is unreliable when comparing different feedstuffs with different physical-chemical properties (NRC, 2001). An *in vitro* method using rumen fluid collected from sheep/cow/buffalo that gives a relative by-pass content for different feed-stuffs has been developed (Ashes *et al,* 1979; Gulati *et al,* 1999; 2001); the values obtained using this method are similar to the *in situ* nylon bag technique. This *in vitro* method was used to measure the degree of natural protection for different protein meals commonly fed to dairy cows in India and data are presented in Table 1. To assist in the formulation of diets for dairy cows and buffaloes, it would be prudent to standardise the methods to be used for estimating the by-pass content of different feedstuffs.

Table 1: Protein Content and Natural Protection or By-pass Content of Oilseed Meals

Meal	Protein (%)	Natural Protection (%)
Soya	50.9	35
Guar Bhardo	53.8	26.5
Cotton	40.5	49.5
Sunflower	31.6	30
Ground Nut	41.5	36.6
Rapeseed	40	41

The degree of natural protection for different protein sources ranges from 26 to 50 per cent and considerable variation can also exist for the same meal depending upon the physical conditions (e.g., temperature, pressure) used during the processing of the oilseed. Such variations in natural protection or by-pass content can also affect the digestibility and bio-availability of essential amino acids; this variability creates difficulties in deciding how much RUP supplement should be included in the diet.

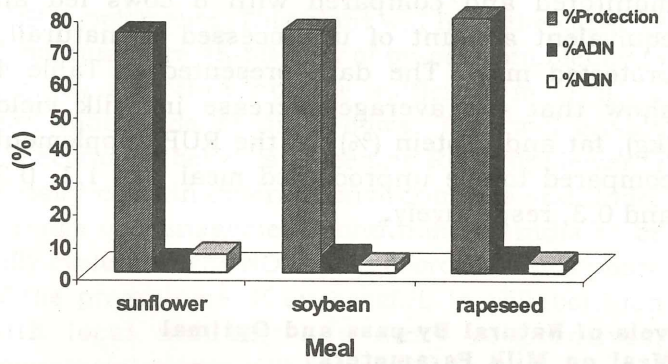
Ideally a RUP or by-pass protein supplement should be:

- Optimally protected from ruminal degradation; if "under protected" the by-pass protein content is inadequate and if "over protected" the digestibility and bioavailability of proteins and amino acids will be reduced.
- Allow maximal protein digestibility and amino acid bioavailability in the small intestine.
- Increase supply of essential amino acids for absorption.

The most economical way of achieving these

nutritional goals is to process oilseed protein meals (26-50% crude protein; CP) with low levels of aldehyde and allow the protein to cure in sealed silos, to increase its by-pass content. This process produces an RUP supplement that consistently contains 70-75 per cent RUP and 25-30 per cent RDP. Another desirable feature of this RUP supplement is the very low proportions of acid detergent insoluble nitrogen (ADIN) and neutral detergent insoluble nitrogen (NDIN), which are nutritional indicators of non-usable nitrogen (see Figure 2). Formaldehyde is permitted as a feed additive in the USA (FDA; 21CFR 573) and is used in many countries eg, Australia, France, United Kingdom etc, to produce by-pass protein supplements.

Figure 2: The protection, ADIN and NDIN Content of Aldehyde Treated Meals



Higher levels of ADIN and NDIN can occur in some heat treated products where the RUP content exceeds 60 per cent and this is most likely due to inadequate control over the temperature and time of oilseed meal treatment. Controlled aldehyde treatment of oilseed meals is less expensive than heat treatment procedures and produces a by-pass protein with desirable nutrient characteristics, examples of this are given in Table 2. The bioavailability of lysine as determined by the method of Carpenter (1960) was approximately 88-92 per cent.

Heat processing of oilseed meals is the other commercial way of producing by-pass protein supplements. Heat denatures the protein and reduces the degradation in the rumen by forming bonds between protein and carbohydrate (Maillard reaction). Careful control of the time and temperature is required during the heating process, under-heating results in a very small increase in RUP, whereas overheating will increase the NDIN and ADIN, reduce the intestinal digestibility of protein and bioavailability of essential amino acids particularly lysine (Satter, 1986; Schwab 1995; NRC, 2001).

The challenge is to produce the most effective form of RUP and demonstrate that inclusion of these supplements in the diet of lactating

Table 2: Nutrient Profile of Sunflower and Rapeseed Protein Meals

	Sunflower Meal		Rapeseed Meal	
	Natural by-pass g/kg	Optimal by-pass g/kg	Natural by-pass g/kg	Optimal by-pass g/kg
CP	330	330	400	400
RUP	99	248	160	304
RDP	231	82	240	96
EAA available for absorption:				
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

EAA—Essential amino acids. Adapted from Gulati et al, 2001.

ruminants produces a worthwhile economic return to dairy farmers.

FEEDING TRIALS WITH OPTIMALLY PROTECTED RUP (BY-PASS) SUPPLEMENTS IN INDIA

A collaborative project sponsored by the Australian Centre for International Agricultural Research (ACIAR), involving the National Dairy Development Board India, (NDDB) and the Commonwealth Scientific Industrial Research Organisation, Australia (CSIRO) was established to produce optimally protected RUP supplements for dairy cows / buffaloes and evaluate their nutritional role and potential economic benefit for village dairy farmers. Feeding trials have been undertaken with by-pass supplements produced from Indian by-products e.g., sunflower and rapeseed meals using the low cost aldehyde process described above.

In the initial feeding trial 0.5, 1 and 1.5 kg of RUP supplement produced from sunflower seed meal (crude protein CP 33%; RUP 75% and RDP 25% of CP respectively) was fed to cross-bred dairy cows (HF xJersey) yielding 7-8 kg per day. The effect on milk yield and quality were compared with another group of cows fed 0.5, 1 and 1.5 kg of unprocessed sunflower meal that had a natural protection or by-pass content of 33 per cent. Further details of the feeding trial can be obtained from Garg *et al,* (2002a). The results in Table 3 demonstrate that feeding optimally protected RUP supplement (1 and 1.5 kg per cow per day) significantly increased milk yield, fat and protein content. Economic analysis showed that feeding 1 kg of RUP supplement, compared to the naturally protected meal, produced the maximal net daily gain, being Rs 9:61 per cow per day.

Further trials were undertaken where 1 kg of RUP sunflower seed meal supplement containing 33 per cent CP, of which 75 per cent was RUP, was fed to 8 cross-bred dairy cows for a 4 week period. Milk yield, protein and fat content were monitored and compared with 8 cows fed an equivalent amount of unprocessed or naturally protected meal. The data presented in Table 4 show that the average increase in milk yield (kg), fat and protein (%) for the RUP supplement compared to the unprocessed meal was 1.1, 0.2 and 0.3, respectively.

Table 3: Effect of Feeding Different Levels of Natural By-pass and Optimal By-pass Sunflower Protein Meal on Milk Parameters

Parameter	Natural By-pass 0.5Kg	Optimal By-pass 0.5Kg	Natural By-passB 1.0Kg	Optimal y-passB 1.0Kg	Natural y-passB 1.5Kg	Optimal y-pass 1.5Kg
Milk yield (Kg)	7.2 ± 0.21	8.0* ± 0.16	6.6 ± 0.20	7.7* ± 0.18	6.2 ± 0.21	7.2* ± 0.19
Milk Fat (%)	4.0 ± 0.06	4.2** ± 0.04	4.0 ± 0.02	4.2** ± 0.05	3.9 ± 0.04	4.2* ± 0.03
Milk Protein (%)	3.3 ± 0.01	3.5* ± 0.01	3.5 ± 0.00	3.8** ± 0.01	3.4 ± 0.00	3.7** ± 0.01

** (P<0.05) ** (P<0.01)*
Adapted from Garg et al. 2002a. Indian Vet J. (in press).

Table 4: Effect of feeding 1Kg of Natural By-pass or Optimal By-pass Sunflower Protein Meal Supplement on Milk Parameters

Parameter	Natural by-pass (30% RUP)	Optimal by-pass (75% RUP)
Milk yield (Kg)	14.1 ± 0.26	15.2* ± 0.28
Milk Fat (%)	4.4 ± 0.10	4.6** ± 0.14
Milk Protein (%)	3.2 ± 0.00	3.5* ± 0.01

** (P < 0.05) ** (P < 0.01)*
Adapted from Garg et al. (2002b). Indian J. Dairy Sci (in press).

Economic analysis revealed that feeding 1 kg of RUP supplement increased net daily income by Rs 9.61 per cow per day (see Garg *et al*, 2002b for further details). Similar increases in milk yield, fat and protein content, were obtained when 1 kg of optimally protected rapeseed meal (40% CP; of which 76% was RUP) was fed to dairy cows for 10 weeks; the net daily income was assessed to be Rs 8:81 per cow per day (Garg *et al*, 2002c).

FUTURE DEVELOPMENTS

More trials are in progress with cows and buffaloes to examine the responses and economic returns with other sources of RUP supplements produced from Indian by-product meals. To date the results of the ACIAR/NDDB/CSIRO collaborative project are promising and this has resulted in the construction of a semi-commercial plant to produce RUP supplements. This plant will have the capacity to manufacture 45-50 tons of by-pass supplements per day and thus provide sufficient material to feed thousands of dairy cows. This will enable the economic benefits of feeding RUP supplements to dairy cows in different environments and under a range of management conditions in India to be fully evaluated; the NDDB will coordinate this phase of the programme. If successful, in collaboration with local industry and dairy cooperatives, commercial plants will be established in different parts of India - they will be the source of a quality controlled and nutritionally defined by-pass feed supplement. Application of this feeding technology has the potential to improve the economic returns for village dairy farmers in India.

REFERENCES

Annison, E. F. and Lewis, D. (1959). Metabolism in the rumen. pp. 92. Methuen and Co Ltd, London.

Ashes, J.R., Gulati, S.K., Cook L.J. and Scott, T.W. (l979). Assessing the Biological Effectiveness of Protected Lipid Supplements for Ruminants. J. Amer. Oil Chem. Soc. 56, No.4. pp. 522-27.

Carpenter, K.J. (1960). The estimation of available lysine in animal protein foods. Biochemical. J. vol:77, pp. 604-610.

Ferguson, K.A. (1975). The protection of dietary proteins and amino acids against microbial fermentation in the rumen. In: Digestion and metabolism in the ruminant, Eds. I. W., McDonald and A. C. I., Warner. University of New England, publishing unit, Armidale, Australia. pp. 448-464.

Gulati, S K., Ryde, I, Kaur, R., Scott, T.W., Garg, M R., Sherasia, P.L. and Singh, D.K. (2001). Emerging Nutritional Technologies For Sustainable Animal Production and Environmental protection - Role of protected nutrients in sustainable milk production. Proceedings of the Xth Animal Nutrition Conference, Karnal, India. pp. 1-9.

Gulati, S.K., Ashes, J.R. and Scott, T.W. (1999). Optimising the Nutritional value of Oilseed proteins for Ruminants In: 90th AOCS Annual Meeting and Expo 1999 held at Orlando, Florida, USA. pp S41-S42.

Garg, M.R, Sherasia, P.L., Bhanderi, B.M., Gulati, S.K. and Scott, T.W. (2002a). Indian Vet Journal. Effect of feeding rumen protected protein on milk production in lactating cows. (in press).

Garg, M.R, Sherasia, P.L., Bhanderi, B.M., Gulati, S.K. and Scott, T.W. (2002b). Indian Journal of Dairy Science. Effect of feeding rumen protected nutrients on milk production in cows and buffaloes. (in press).

Garg, M.R, Sherasia, P.L., Bhanderi, B.M., Gulati, S.K. and Scott, T.W. (2002c). Australasian Journal of Animal Science. Effect of feeding protected protein on milk production in lactating cows. (in press).

NRC, 2001. "Nutrient Requirements of Dairy Cattle, 7th Ed. National Academy of Science–National Research Council, Washington, DC.

Satter, L.D. (1986). Protein supply from undegraded dietary protein. J. Dairy Sci. vol 69. pp. 273-2749.

Schwab, C.G. (1995). Protected proteins and amino acids for ruminants. In: Biotechnology in animal feeds and animal feeding. Eds R.J. Wallace and A. Chesson, VCH press, Weinheim, Germany. pp. 115-141.