Role of Bypass Protein in Feeding Ruminants on Crop Residue Based Diet – Review –

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ABSTRACT : Measurement of DCP is considered inadequate and unsatisfactory means of assessing the protein value of the diet as no distinction is made between the digestion in ferestomach and in the small intestine.

Protein meals should be classified on the basis of rumen degradable protein (RDP) and rumen undegradable protein (UDP). Usually, protein meals naturally available with high level of UDP or bypass protein value should be preferred for incorporation in the diet of lactating and growing animals. However, if such resources are non-available or are expensive, protein meals having high degradability can be carefully subjected to heat or formaldehyde treatment to achieve desired level of rumen bypassability. Various studies conducted the world over have revealed that bypass protein feeding to ruminants, especially when animals are fed on crop residue based basal diet, help increasing feed conversion efficiency in growing and lactating ruminants.
(Key Words: Bypass Protein, Rumen Degradable Protein, Undegradable Protein, Digestible Crude Protein)

INTRODUCTION

Proteins form one of the most significant constituents of the ruminants' ration. It is, therefore, of paramount importance to ensure that this constituent is utilised with high efficiency. Measurement of DCP, although a useful parameter in a ruminant diet, is now considered inadequate and unsatisfactory means of assessing the protein value of the diet. This is mainly because no distinction is made between digestion in the forestomach (production and uptake of ammonia) and digestion in the small intestine (uptake of amino acids).

Proteins in ruminant diet are degraded to variable extents, depending upon their solubility and also the activity of micro-organisms in the rumen. Protein degradation products, such as ammonia, amino acids and peptides are utilised in turn by the microbes for synthesising 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 food proteins which remain undegraded in the rumen but are subjected to enzymic digestion in the lower tract. In the process of microbial degradation, the biological value (BV) of high quality proteins is often depleted.

The discovery by McDonald (1948) that soluble dietary proteins are extensively degraded to ammonia in the rumen and the subsequent observations that proteins or amino acids administered postruminally resulted in greater N retention compared to when these were administered directly in the rumen led to attempts to find ways of protecting soluble, high quality dietary proteins from microbial degradation within the rumen. There are several alternatives for reducing or preventing the degradation of proteins in the rumen, so that they would pass to the lower gut for subsequent digestion viz., closure of reticulo-rumen groove (Orskov and Benzie, 1969; Orskov and Fraser, 1969) by feeding liquid diets or by feeding dietary proteins subjected to heat treatment (Chalmers et al., 1954; Tagari et al., 1964; Chalmers et al., 1964; Bhargava et al., 1975; Sengar and Mudgal, 1982), tannic acid treatment (Leroy et al., 1965; Delort Lavel and Zelter, 1968; Bhargava et al., 1973a) or formaldehyde treatment (Ferguson et al., 1967; Reis and Tunks, 1969; Faichney, 1971; Sengar and Mudgal, 1982). Out of these, the most promising approaches seem to be the modification of proteins by heat and HCHO treatments in order to decrease the solubility and hence susceptibility to microbial degradation in the rumen. However, since feeding of protected proteins may reduce the availability of N in the rumen, it is desirable to supplement diets with adequate amounts of non-protein N source, so that the microbial protein synthetic activity in the rumen is efficient.

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Protein feeds are scarce and expensive therefore judicious use has to be made of the existing protein resources. In this article, work carried on the various aspects of feeding bypass protein in relation to overall N metabolism in large ruminants has been reviewed.

Estimation of potential degradability of proteins in the rumen

The feeding system put forward by Agricultural Research Council (ARC, 1980) and National Research Council (NRC, 1989) proposes that the nitrogen compounds in feed stuffs should be classified in terms of their rumen degradable nitrogen (RDN) and rumen undegradable nitrogen (UDN) contents. Different protein sources differ in their protein degradability even under the identical rumen environments, probably due to variations

Table 1. Percent CP, RDP and UDP values of protein sources at rumen outflow rate of 0.05/h

Protein source	CP	RDP	UDP	UDP as % of total CP	Reference
G. N. E	40	36	4	11:	Manget Ram and Gupta (1994)
Cotton seed cake	40	22	18	44:	
Wheat bran	17	13	4	25:	
D. O. R. B.	16	10	6	38:	
G. N. cake	41	39	2	4:	Gupta and Gupta (1984)
Til cake	39	29	10	25:	
Mustard cake	37	33	4	12:	
Soyabean meal	44	39	5	12:	
G. N. cake	39	18	21	53:	Upadhyaya and Gupta (1988)
Linseed cake	32	13	19	58:	
G. N. cake	44	30	14	32:	Sampath and Sivaraman (1985)
Gingelly cake	34	29	5	14:	
Ruber seed cake	27	19	8	31:	
Coconut cake	28	6	22	81:	
G. N. cake	46	9	37	70:	Reddy and Prasad (1985)
G. N. E.	49	15	34	69:	
Cottonseed cake	40	7	33	82:	
Safflower cake	21	13	8	39:	
Tobacco seed cake	29	12	17	57:	
Silk cotton seed cake	33	26	7	22:	
Niger seed cake	34	11	23	67:	
Sunflower seed cake	34	16	18	53:	
Cotton seed meal	24	12	12	50 (43):	Negi et al. (1989)
G. N. cake	32	25	7	23 (19):	
Linseed cake	27	11	16	59 (54):	
Mustard cake	43	36	7	14 (13):	
Soyabean meal	50	19	31	62 (57):	

( ) DUP : digestible undegraded protein, – UDP corrected for ADF-N.

in rumen out flow rates. The degradability of various proteins could be compared by determining either 1/2-CP in the rumen (Gupta and Gupta, 1985) or by the other methods developed by Orskov and McDonald (1979) and Miller (1980), using nylon bag technique. The estimates of potential rumen degradability of the naturally occurring protein sources can, thus, be helpful (table 1) in formulating rations based on the concept of rumen degradable protein (RDP) and rumen undegradable protein (UDP) (Preston and Leng, 1987).

There is variability in values of RDP and UDP of different protein sources, as well as the same protein source, depending upon its origin, method of processing, extent of adulteration, nature of host's animal diet alongwith the level of feeding.

Ration can be formulated on the basis of their RDP and UDP values, it may still not be always economical as most of feed ingredients have low level of UDP. The UDP values also need to be corrected for unavailable ADF-N (Negi et al., 1989).

Protein sources having high content of available UDP would be ideal for incorporation in production concentrate mixtures. But protein sources having low content of available UDP can be subjected to formaldehyde or heat treatment to enhance their UDP content. Protein meals having high proportion of RDP such as groundnut meal, soyabean meal, gingelly cake etc. can be subjected to such treatments. However, caution is necessary to avoid the indiscriminate use of HCHO from animals health point of view and to avoid over-protection of the protein, rendering it completely undegradable in the rumen, thereby, depriving the rumen microbes of their RDP requirements and making it indigestible lower down the gut. Many workers have reported RDP and UDP value of various feed ingredients, as such or with treatments (Chaturvedi and Walli, 1995; Martillotti et al., 1995; Reddy et al., 1992; Gupta et al., 1992; Cozzi et al., 1992 and Sampath et al., 1989).

Protection of proteins for increasing their rumen bypass value (UDP)

Considering that many of the feed ingredients have low UDP content, it is necessary that these feed ingredients are subjected to formaldehyde or heat treatment. However, it is important to determine the minimum possible level of HCHO to be used for treatment so that the level of UDP is raised to about 70 percent. Attempts were made to develop regression equations for estimating the appropriate level of HCHO for treatment of some oil cakes (available for use in the cattle feed industry) for raising UDP level to 70 percent of the total protein moiety (table 2). The optimum level of HCHO (g/100 g CP) required for treatment varied with different oil cakes, having a low of 0.50 for linseed cake and a high of 2.07 for sesame cake. More detailed studies on this aspect are needed.

Table 2. HCHO treatment for attaining 70 percent UDP calculated using model of Orskov and McDonald (1979) at 0.05/h rumen outflow rate

Protein meal	Linear equation of order $Y = a + bX$	Level of HCHO to attain 70% UDP (g/100 g CP)
Linseed cake	Y LC=40.58 − 20.97 X ($r=0.98$, $p < 0.01$)	0.50
Groundnut cake	Y GNC=99.16 − 59.79 X ($r=0.97$, $p < 0.01$)	1.16
Soyabean meal	Y SM=80.48 − 42.46 X ($r=0.97$, $p < 0.01$)	1.19
Mustard cake	Y MC=99.63 − 44.99 X ($r=0.95$, $p < 0.01$)	1.48
Sesame cake	Y SC=76.07 − 22.24 X ($r=0.99$, $p < 0.01$)	2.07

Like HCHO treatment, heat treatment also differs in its efficacy with protein meals. When grounded cake was heat treated at 150 degree C, protein solubility was reduced from 23.65 to 10.40 percent. However, reduction in solubility was only from 14.3 to 10.30 percent in soyabean meal, under similar conditions (Walli, 1995).

It seems practicable to use available protein resources which naturally contain high degree of UDP for ruminants feeding as such or for incorporation in compounded cattle feed. However, if bypass protein sources are either unavailable or uneconomical, the protein sources having high proportion of RDP can be treated with lowest possible level of either heat or HCHO to raise the proportion of UDP.

Effect of protection on *in sacco* nylon bag protein degradability

On treatment with HCHO, nylon bag protein degradability of groundnut cake, mustard cake, sesame cake and soyabean meal was significantly reduced (Gupta and Gupta, 1985). The nylon bag protein degradability also decreased progressively with the increase in the level of HCHO treatment. This is attributed to HCHO binding the proteins by the formation of methylene bridges

(Ferguson et al., 1967 and Fraenkel-Conrat and Oleot, 1948) which makes them resistant to microbial attack (Walker, 1964). These results also revealed that the extent of protection obtained by the use of HCHO treatment was influenced by the type of protein present in the cakes.

The HCHO treatment exerted minimum influence on sesame cake and maximum on GNC. In other words, the proteins present in GNC were more amenable for protection by HCHO treatment than the protein present in other cakes.

Similarly, it was not possible to reduce ruminal protein degradability of sunflower meal with treatment. The pepsin digestibility of untreated or heat treated meal was same. Like HCHO treatment, different cakes respond differently to heat treatment as indicated by nylon bag degradability studies (Veresegyhazy et al., 1989).

Effect of feeding bypass protein (Natural and Protected) on rumen and blood metabolities

Various workers reported that with the HCHO treatment, *in vitro* ammonia release was reduced, due to reduction in protein solubility. Again, different cakes responded differently to reduction in solubility with HCHO tretment (Walli et al., 1980). Gupta and Gupta (1985) treated groundnut cake, mustard cake, sesame cake and soyabean meal with HCHO at 0, 0.5, 1.0 and 1.5 g HCHO per 100 g protein.

It was observed that with the increasing level of HCHO, *in vitro* ammonia was inversely affected. In another experiment, Upadhyaya and Gupta (1988) observed similar trend with cotton seed cake, groundnut cake and linseed cake. However, no significant effect was exerted at any level of HCHO treatment on fish meal, where *in vitro* ammonia release was reduced from 36 to only 34 percent.

Tiwari et al. (1993) reported that when buffaloes were fed groundnut cake in place of guar seeds, ammonia-N in rumen fluid and ammonia and urea-N in blood plasma were higher. In another experiment, 5 mature beef cows were fed native grass, soyabean hulls and soyabean meal, without or with bypass proteins (blood meal or maize glutten meal). Rumen ammonia concentrations decreased when bypass protein composed 50 percent of supplemntal protein (Scott et al., 1991). Similarly, Nicholson et al. (1992) reported that rumen fluid ammonia-N was increased after feeding urea and soyabean meal compared to control or fishmeal supplementation. Grubic (1991) reported that increased level of UDP in the diet increased pH and percent of acetic acid and decreased percent of propionic acid in rumen fluid. UDP level did not influence blood glucose, blood urea and total protein levels.

Concentrates containing soyabean meal, meat meal, maize glutten meal, HCHO treated soyabean meal and blood meal were tested for CP disappearance in rumen of sheep, which was in descending order. It was also reported that total VFA conc and pH were not affected in the rumen with the source of portein in concentrate (Terramoccia et al., 1989).

Significance of fermentable N along with bypass protein

Of the total protein supplied to animals through diet, a part of it should be fermentable in the rumen to meet nitrogen requirements of microflora in the rumen. Inadequate fermentable nitrogen in the diet will affect microbial growth and reduce fiber digestion in the rumen. Bengal goats were fed different levels of fish meal (a source of bypass protein) with or without free access to urea molasses block (a source of fermentable nitrogen and energy). It was reported that fermentable nitrogen had significant effect on weight gain when given along with bypass protein, compared to when only bypass protein source was given (Huq et al., 1996).

Several workers reported when fermentable nitrogen source was provided along with bypass protein source, it resulted into increase in microbial growth, feed intake, digestibility, significantly higher N balance, higher growth rate, higher milk production and improved reproduction (Senger et al., 1994; Calzadilla et al., 1992; Giri and Dass, 1993; Harris (Jr.), 1993; Mastika et al., 1994; Promma et al., 1992; Meissner et al., 1992; Henning, 1990 and Newbold and Rust, 1990).

Effect of feeding RDP and UDP on bacterial growth rates in rumen and N balances

Several workers have observed that a high bacterial growth rate is achieved on straw diets if these are urea-impregnated or ammoniated. Thus, when adult male buffaloes were fed on wheat straw impregnated with urea at 1, 2 or 3 percent level and supplemented with 15 percent molasses, the bacterial production rates (g/day) were: 144 ± 1.4, 210 ± 2.4 and 210 ± 5.2, recording a significant ($p < 0.01$) increase with the increase in the levels of urea impregnation (Sharma and Gupta, 1984b). The corresponding levels of rumen NH_3-N (mg/100 ml SRL) were 13.1 ± 0.15, 24.1 ± 0.89 and 29.8 ± 0.19 ($p < 0.01$). However, while the animals fed on 1 percent urea impregnated straw exhibited a negative N balance (−4.16 ± 0.56 g/day), the animals in other gruops exhibited a positive N balance of 3.6 ± 1.8 and 4.2 ± 0.6 g/day, respectively.

Although the type of feed and the level of feed intake have a great bearing on the rumen bacterial production rate, a bacterial production rate of 210 g/day (or 67 ± 5.6 g/kg DOMI) on 2 percent urea impregnated wheat straw complete rations with 15 percent molasses, 1 percent mineral mixture and adequate vitamin A can maintain adult buffaloes in positive N balance. In another experiment (Upadhyaya and Gupta, 1988) where 3 groups of male buffaloes were fed on untreated wheat straw + concentrate mixture (Group 1), 4 percent urea (ammonia) treated wheat straw (40% moisture) with 15 percent molasses (Group 2) and without any molasses (Group 3), the rumen NH_3-N levels (mg/100 ml SRL) in the three groups were: 8.1 ± 0.8, 9.3 ± 2.2 and 15.0 ± 1.7 respectively. The corresponding rumen bacterial production rates (g/day) were: 125 ± 7.6, 185 ± 17.9 and 188 ± 4.26, indicating a spurt in microbial synthesis on feeding ammoniated straw that could maintain animals in positive N balance even without supplementation with molasses (Group 1 : 13 g; Group 2 : 15 g and Group 3 : 5.6 g/day). Other workers have reported that provision of urea-molasses block licks on crop residue based diet improved microbial protein synthesis form 76 g to 200 g per day in case of paddy straw (Madhu Mohini and Gupta, 1991) and from 54 g to 193 g per day in case of wheat straw (Garg and Gupta, 1992).

The digestible crude protein (DCP) moeity in low grade roughages is generally assumed to be nil. But it has been observed that when evaluated in terms of rumen degradable nitrogen (RDN) and available undegradable nitrogen (UDN), wheat and rice straws meet upto 40 and 60 percent respectively of maintenance requirement of animals (Negi et al., 1988). It seems quite practicable to meet the maintenance protein requirement of animals by feeding low grade roughages supplemented with rumen degradable source of nitrogen like urea. This would save a considerable part of protein feeds for production purposes.

Sharma and Gupta (1984a) supplemented 3 groups of rumen fistulated adult male Murrah buffaloes either solely with untreated GNC (UN-GNC, Group I) or the same in combination with HCHO treated (1.25 g/100 g CP) GNC (T-GNC) in different proportions (Group 2: 66% UN-GNC + 33% T-GNC; Group 3 : 33% UN-GNC + 66% T-GNC). Wheat straw *ad lib* formed the roughage part of the ration and vitamin A was supplemented through drinking water. It was observed that rumen NH_3-N level (mg/100 ml SRL) declined progressively and significantly ($p < 0.01$) from 12.89 ± 0.67 in Group 1 to 9.52 ± 0.09 in Group 2 and 7.04 ± 0.08 in Group 3. Obviously with the increase in the level of incorporation of HCHO treated GNC in the ration, there was a progressive decline in the degradability of GNC in the rumen. The mean bacterial production rates determined by using ^{35}S, were 200, 202 and 140 g/day in the respective groups ($p < 0.01$). Thus, the feeding of bypass GNC at 33 percent level did not affect the bacterial production rates in the rumen. On the other hand, the N balances significantly improved in Groups 2 and 3 (4.99 ± 0.48; 9.46 ± 0.69 g/day) in comparison to Group 1 (0.94 ± 0.59 g/day) where GNC without HCHO treatment was fed to the animals.

However, when viewed from the overall N economy of the animals even at the lowest bacterial production rate of 100 g/day (59.4 g/kg DOMI), the animals exhibited much higher N balances (+ 9.46 g/day) as the level of bypass GNC was increased to 66 percent. Since the main objective of feeding the bypass proteins is to increase efficiency of their utilisation, it would be desirable to allow only a part of the protein to be degraded in the rumen to provide the fermentable nitrogen and necessary branched chain carbon skeletons for increased microbial protein synthesis. The average percent efficiency of N incorporation into microbial protein in the 3 groups was 29.7, 30.9 and 21.5 respectively. Although, the efficiency of N incorporation in Groups 1 and 2 was similar, and significantly higher than in Group 3, the incorporation of 66 percent T-GNC greatly improved the overall N economy of the animals in the latter group.

In another experiment, Upadhyaya and Gupta (1988) observed that the bacterial production rates in the rumen of crossbred males decreased from 248 ± 6 g/day in control ration to 218 ± 10 and 155 ± 14 g/day when HCHO treated GNC was incorporated replacing 1/3rd or 2 /3rd of untreated GNC in the concentrate ration. Interestingly again the levels of NH_3-N (mg/100 ml SRL) as percent of total N in the rumen decreased significantly from 33 ± 2.7 in control group to 29 ± 3.2 and 26±2.3 respectively in groups receiving increasing levels of HCHO treated GNC in their ration. Thus, with the increase in the level of bypass protein, NH_3-N levels in the rumen are expected to decrease, affecting the overall production of bacterial protein in the rumen. Since the efficiency of utilisation of proteins is greater when these bypass the rumen avoiding degradation in the rumen, the feeding of bypass proteins is economical for an overall N economy of the animals, but could be further beneficial if the fermentable nitrogen requirements of ruminal microflora are taken care of by incorporating non-protein nitrogen sources in diet at appropriate levels.

Effect of feeding fermentable N and bypass protein on growth rate of animals

Upadhyaya and Gupta (1988) fed 4 groups of crossbred male calves on untreated wheat straw plus concentrate mixture (Group 1), ammoniated wheat straw plus concentrate mixture having HCHO treated GNC at 0 percent (Group 2), 33 percent (Group 3) and 66 percent (Group 4) levels of replacement. It was observed that the calves in group 4 attained the highest daily growth rate (693 ± 70 g) as compared to Group 1 (530 ± 70 g), Group 2 (526 ± 95 g) and Group 3 (614 ± 75 g).

In growing male crossbred calves fed untreated straw and HCHO treated groundnut cake, cost per kg gain was less compared to calves fed urea treated straw and untreated groundnut cake (Vinod Kumar and Walli, 1994). In two Groups of growing heifers receiving silage and concentrate mixture, daily growth rate was 0.39 and 0.37 kg. However, when fish meal, as a source of bypass protein, was daily incorporated in concentrate mixture @ 0.3 kg, daily growth rate increased to 0.65 and 0.75 kg in 2 groups (Calzadilla et al., 1992).

In a growth trial, 140 feed lot steers were given basal diet containing 18% lucerne hay, 10% sudangrass hay, 16% steam flaked maize, 2.5% yellow grease, 6% molasses and supplemented with 0, 2, 4 and 6 percent bypass protein (blood meal, meat and bone meal, fishmeal 1 : 1 : 1) in group I, II, III and IV, respectively. Urea was the sole source of supplemental nitrogen. Incorporation of bypass protein source in the ration at 2 percent level increased growth rate and efficiency of gain by 13.4 and 8.4 percent, respectively (Zinn and Owens, 1993). In other experiment, Grubic (1991) reported that in cattle increased intake of bypass protein increased daily gain, body weight, DM intake energy and protein. Smith et al. (1990) observed increase in growth rate by 0.30 lb/day on providing different sources of bypass protein meal to autumn weaned calves in two groups. However, supplements containing additional high bypass protein did not increase gains compared with the maize based energy supplement.

One year old buffalo calves in seven groups of three each were fed ammoniated wheat straw (69.5%), molasses (29%), common salt (0.5%), minerals (1.0%) and vitamins and were fed 0, 25, 50, 100 or 200 g fish meal/ day ; two additional groups were given fishmeal 25 and 50 g per day along with 500 g deoiled rice bran. DM intake from straw increased with increased supplementation of fishmeal. Daily live weight gains were 105, 125, 209, 230 and 301 g in the groups given fish meal 0, 25, 50, 100 and 200 g, respectively, and 323 and 389 g in groups given fishmeal and deoiled rice bran. It was concluded from these studies that feeding regime containing ammoniated wheat straw along with other nutrients and small amount of bypass protein is suitable for buffaloes, experiencing drought and famine (Singh and Mehra, 1990).

Similarly, several other studies reported that urea feeding, a source of fermentable N, through urea molasses mineral block and concentrates containing source of bypass protein help in meeting requirements of growing calves fed crop residue based diet (Manget Ram and Gupta, 1991 ; Madhu Mohini and Gupta, 1991 b ; Srinivas et al., 1993).

Effect of bypass protein feeding on milk production

Bypass protein feeding has been shown to be quite useful in increasing milk production, especially when animals are energy deficient. In developing countries, animals are fed pre-dominantly on crop residues based diet with little supplementation of green fodder and/or concentrates, depending upon availability and economic considerations. Feeding bypass protein directly or through concentrate mixture at various levels has shown improvement in milk production in medium and high yielding cows. Experiments conducted in this respect by some of the workers are discussed here.

Twelve lactating cows, yielding average 10 litres of milk, were divided into two groups of six each and fed isonitrogenous and isocaloric concentrate mixture, according to milk production. Concentrate fed in group A had 35 percent of total CP as bypass protein, while in group B it was 55 percent. Animals in both the groups were fed paddy straw *ad lib* and each 5 kg of para grass daily. In four months trial period, average daily milk yield in group B was 9.81 kg compared to group A where milk yield was 8.50 kg. The amount of byppass protein fed per litre of milk was higher in these studies, compared to ARC (1980) recommendations (Ramchandra and Sampath, 1995). These workers further opined that requirement of UDP (bypass protein) for lactating cows producing approximately 10 kg milk per day, with the feeding regime of paddy straw as main roughage source, may be much higher than the ARC (1980) recommendations.

Eighteen lactating goats were divided into three groups of six each, based on milk yield. Besides feeding similar green oat forage in all the groups, concentrates fed in three group had RDP : UDP ratio of A, 75 : 25 ; B, 55 : 45 ; C, 55 : 45, for 120 days. Diet C had 20 percent less CP, compared to A and B. Overall daily UDP (bypass protein) intake in groups A, B, and C was 48 g, 73 g and 61 g, respectively. Goats fed on diet B had significantly high milk yield (1.56 kg/day) compared to diets A (1.34

kg/day) and C (1.34 kg/day). Goats in group B had better feed conversion efficiency of 1.39 compared to group A, 1.10 and C, 1.24 kg milk per kg DM intake (Misra and Rai, 1996).

Chiou et al. (1995) fed 24 lactating cows in three groups with similar roughages and concentrates comprising maize silage, lucerne hay, maize and soyabean meal, with CP and UDP levels of 16.5 and 33.5% (diet 1), 16.5 and 37.0% (diet 2) or 15.0 and 37.0% (diet 3), respectively. The diets were formulated to meet the CP (diet 1), UDP (diet 2) and UDP:CP (diet 3) requirements listed by the National Research Council (NRC) and were fed for 9 weeks. The results suggested that diets formulated according to UDP requirements listed by the NRC are better than those formulated according to the CP requirements, with respect to milk yield and efficiency of milk production.

As stated in the earlier part of this article, adequate amount of fermentable nitrogen (rumen degradable protein) in the diet is essential for experssion of beneficial effects of bypass protein feeding. Holter et al. (1993) fed commercial bypass protein, fat supplement to lactating HF cows and observed that this supplementation in the diet of lactating cows was not effective if its use reduced DM intake or if degradable protein intake was inadequate.

Total forty lactating crossbred cows grazed on Brachiaria decumbens pasture, were randomly allocated to four treatments for 188 days. Treatment groups were given daily supplements of bypass protein through cottonseed meal (CSM) at 0, 0.5 or 1.0 kg DM along with mixture of urea, sulphur and concentrates. Controls were not given any supplements. Treatments increased milk yield. Cows in all the treatments lost weight but those receiving zero CSM had highest weight loss (−299 g/day). Pregnancy rates in treatment groups was significantly higher at 66 percent compared to control, which was 30 percent (Anjola et al., 1990).

Effect of feeding various bypass protein sources to lactating cows was compared. These were soyabean meal, HCHO – treated soyabean meal, maize glutten meal, blood meal and meat meal, incorporated at 10 percent level in concentrates for studying effect on milk yield and milk composition of lactating cows. Highest milk fat content was observed in cows given blood meal supplement, while the highest daily milk production was observed in cows given maize gluten meal supplement (Kim et al., 1992).

Lactating Brahman cows were grazed on ryegrass overseeded coastal bermudagrass pasture with *ad lib* bermudagrass hay given supplements containing 38.1 (low), 56.3 (medium) or 75.6 percent (high) rumen undegradable intake protein (UIP) from day 7 to 119 days after calving. Medium – UIP cows produced more milk compared to high or low-UIP groups, but milk yield in adult cows was not influenced by diet. Overall pregnancy rate was higher in medium (61.5%) and high-UIP (56.4%) groups than in the low-UIP (43.2%) group (Triplett et al., 1995).

It is well understood now that the absorbed protein is the result of both undegradable protein and microbial protein production in the rumen. In majority of the expreiments OM fermentability in the rumen decreased with increase in proportion of rumen bypass protein or undegradable protein in the diet, resulting into decrease in microbial protein production in the rumen. Komaragiri and Erdman (1992) conducted an experiment on HF cows, fed increasing levels of undegradable proteins in the diet. These workers reported that dietary undegradable protein exerted greater effects on milk yield only with the advancement of lactation.

In another experiment, 18 dairy cows were fed total mixed ration (TMR) in three groups of six cows each, desingned to meet both degradable protein (DIP) and undegradable protein (UIP) requirements. Cows in experimental groups were fed additional 0.36 kg/day of supplementary protein from a highly degradable source (SBM) or a highly undegradable source (FM). These studies revealed that supplementary DIP or UIP did not increase milk production (Porter, 1990).

These studies reveal that bypass protein feeding has a special role to play under those situations, where animals' basal diet is poor, comprising straws/stovers, grasses etc., as is the case in developing countries. Under such situations, bypass protein feeding even above recommended levels can lead to increase in milk yield and improved reproductive performance, provided supplemented along with adequate fermentable nitrogen, minerals etc.

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