The establishment of a protein degradability data base for dairy cattle using the nylon bag technique. 1. Protein sources

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The protein degradability of various South African ruminant feed protein sources was determined in the rumen of cannulated lactating dairy cattle. The effective protein degradability was calculated at different fractional outflow rates, using the nylon bag technique. The degradability values ranged from 96,2; 91,9 and 88,7% for whole sunflower seeds to 32,2; 25,1 and 23,0% for blood meal at fractional outflow rates of 0,02; 0,05 and 0,08/h, indicating a large variation in the resistance of protein sources to ruminal breakdown. It is proposed that when protein sources are bought they should be evaluated on their rumen undegradable protein (UDP) content rather than crude protein content, as this would reflect the true nutritional value of a protein source more accurately.

Die proteïendegradeerbaarheid van verskeie Suid-Afrikaanse herkouer voer-proteïenbronne is bepaal deur gebruik te maak van lakterende gekannuleerde melkkoeie. Die effektiewe proteïendegradeerbaarheid is bereken by verskillende fraksionele uitvloeitempo's deur gebruik te maak van die kunsveselsakmetode. Die proteïendegradeerbaarheidswaardes het gevarieer van 96,2: 91,9 en 88,7% vir heel sonneblomsaad tot 32,2; 25,1 en 23,0% vir bloedmeel by fraksionele uitvloeitempo's van 0,02; 0,05 en 0,08/h wat 'n aanduiding gee van die groot verskille wat bestaan in die weerstandbiedendheid van proteïenbronne teen afbraak in die rumen. Daar word voorgestel dat wanneer proteïenbronne aangekoop word, evaluasie eerder moet geskied op die basis van nie-degradeerbare-proteïeninhoud (UDP), as ruproteïeninhoud, aangesien dit die ware voedingswaarde van 'n proteïenbron baie meer akkuraat reflekteer.

Keywords: Protein degradability data base, nylon bag, dairy cattle, UDP

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Introduction

Recent systems for estimating protein requirements are based upon the concept that protein requirements for ruminants can best be met by supplying sufficient nitrogen for rumen microbes (RDP) plus additional protein which will pass undegraded through the rumen (UDP) to balance any deficit which may exist between the intestinal supply of microbial protein synthesized in the rumen and tissue requirements for intestinally absorbed amino acids (Burroughs, Nelson & Mertens, 1975; Vérité, Journet & Jarrige, 1979; ARC, 1980; Satter, 1982). Since rumen degradability determines both the degradable and undegradable fractions of dietary protein, the availability of a rapid and reliable method for determining protein degradability is crucial in the implementation of the new protein systems (Ha & Kennely, 1984).

All the methods used for estimating protein degradability have shortcomings (Satter, 1986). Protein solubility in particular can be a misleading measure (Stern & Satter, 1984) and is not suitable for estimating protein degradability across a variety of feedstuffs. It can, however, be a useful relative measure of protein degradability for feedstuffs that have undergone heat or chemical treatment. An indirect measurement of degradability can be obtained by measuring the quantity of protein flowing to the abomasum or duodenum and involves animals surgically prepared with cannulae. Reliable methods for measuring of digesta flow and separation of microbial, endogenous and dietary protein are also required (Stern & Satter, 1982). *In vivo* estimates of this kind are labour intensive, time consuming, and subject to considerable error and therefore of limited use for large scale determinations of degradability (Stern & Satter, 1984; Hvelplund, 1986). Determination of protein degradability by measuring the flow of non-microbial protein and amino acids to the duodenum will remain a research technique unsuitable for routine evaluation of feeds (Miller & Ørskov, 1986). Estimates of degradability made by incubation with rumen fluid or proteases for a single arbitrary time period do not describe the rate of degradation of protein, and, therefore can be expected to be poor predictors of degradation under varying conditions *in vivo* (Miller & Ørskov, 1986).

The *in sacco* technique (nylon bag, *in situ*) has been suggested as an alternative method (Mehrez & Ørskov, 1977). This technique provides a relatively easy and rapid method for determining the protein degradability, requiring only a rumen-fistulated animal and minimal chemical analysis (Ha & Kennely, 1984). This technique involves suspending nylon bags containing different feedstuffs in the rumen and measuring protein disappearance at various time intervals. Models for the quantitative estimation of protein degradation from nylon bags have been suggested in recent studies

(Ørskov & McDonald, 1979; Mathers & Miller, 1981; Kristensen, Møller & Hvelplund, 1982). At present the nylon bag technique is the best method available for routine determination of protein degradability (Ørskov & McDonald, 1979; Kristensen, *et al.*, 1982; Lindberg, 1983; Setälä, 1983; ARC, 1984; Miller & Ørskov, 1986). Apart from the ARC, the Nordic protein evaluation group also standardized and adopted the nylon bag technique for compiling protein degradability tables (Madsen, 1985). Good predictions of *in vivo* degradation with this method have been shown (Stern & Satter, 1980; Mathers & Miller, 1981; Zinn, Bull & Hemken, 1981; Loerch, Berger, Plegge & Fahey, 1983; Madsen & Hvelplund, 1985).

However, this technique has some limitations as pointed out by Meyer & Mackie (1986), with critical aspects discussed by Lindberg (1985). The nylon bag technique measures essentially the rate of disappearance from the nylon bag rather than the actual degradation. Furthermore, samples in the bag are not subjected to chewing and rumination by the animal. Microbial contamination may also cause considerable error as pointed out by Varvikko & Lindberg (1985) and Kennedy, Hazlewood & Milligan (1984), particularly with feedstuffs low in protein. Therefore the data obtained from this technique should be interpreted with caution and should be compared with *in vivo* studies whenever possible. Nevertheless, although the nylon bag technique is an imperfect and empirical approach, it incorporates animal and microbial factors helpful in quantitating protein degradation in the rumen (NRC, 1985).

Most of the *in vivo* estimates of ruminal protein degradation have been done in sheep. Care must be exercised in extrapolating results from sheep that may be eating at maintenance or twice maintenance levels to lactating cows consuming three or four times maintenance level. There are differences between sheep and cattle with regard to retention time of feed in the rumen, how thoroughly feed is chewed and the type of diet normally fed. Therefore it may be inappropriate to apply these values to high-producing dairy cows (Satter, 1978; Siddons & Paradine, 1983; Ha & Kennely, 1984; Erasmus, 1985).

The ARC (1980) rank feeds into classes A, B, C and D to cover the degradability range 0,71 – 0,90; 0,51 – 0,70; 0,31 – 0,50 and < 0,31 respectively. Mean degradability values of 0,8; 0,6 and 0,4 were assigned to the first three classes. Such a wide classification could result in large discrepancies in the supply of UDP and so reduce the effectiveness of the system in practise (Filmer, 1982). Using standard degradability values from Europe or USA seems inappropriate. They would also most probably not cover the appropriate feedstuffs used in the Republic of South Africa. Therefore it is considered necessary to develop a national protein degradability data base for use in dairy cattle feed formulations.

The objective of this study was to initiate such a protein degradabillty data base by determining the protein degradability of the most common protein sources normally used in the formulation of dairy cattle diets. Protein degradability values for cereals, cereal byproducts and roughages will be published in future issues of journals.

Experimental procedures

Animals and diet

Four lactating Friesian/Holstein cows with average live mass of 570 kg, and average production of 5000 kg during the previous lactation were used. Each animal was fitted with a rumen cannula (100 mm internal diameter). A practical dairy cattle diet (Table 1), formulated to contain some of the major protein sources used by the balanced feed trade, was fed as a complete diet and offered twice daily for *ad libitum* intake.

Protein sources

All the feedstuffs were obtained commercially and the crude protein contents are as indicated in Table 2. All the feedstuffs were ground in a Wiley mill with a 2-mm screen before weighing into nylon bags for incubation in the rumen.

Nylon bag technique

Bags were made of nylon cloth (Rhologan Engineering, P O Box 84158, Greenside, 2034 Republic of South Africa) having an average pore size of 53 μm. The nylon bags (14 × 9 cm) were sown with a double row of stitching with rounded corners to allow easy removal of particulate material. The seams were sealed with a contact adhesive and closed with nylon string (Ørskov, Hovell & Mould, 1980).

Approximately 5 g (air dry) of the test proteins were placed in the nylon bags which were tied to a round

Table 1 Composition of the complete diet fed to the four rumen-cannulated cows

Ingredients	%[a]
Lucerne hay	15,0
Eragrostis curvula hay	15,0
Wheat straw	15,0
Maize meal	40,0
Urea	0,5
Fish meal	3,0
Sunflower oilcake	4,0
Soybean oilcake	3,0
Cottonseed oilcake	3,0
Salt	0,7
Dicalcium phosphate	0,5
Commercial vitamin and trace mineral premix	0,3
Composition	
Crude protein	15,2
Crude fibre	18,2
ME (MJ/kg DM)	10,3

[a] Dry matter basis

Table 2 Crude protein (CP) content of feedstuffs (DM basis) used for *in situ* incubation and parameters of the linear regression of the natural logarithm of N remaining in the bag vs time

Feedstuff	% CP	*a*	K_d	*SE* K_d[e]
Blood meal	81,9	0,19	-0,0038	0,00074
Brewers dried grains (sorghum)	30,7	0,09	-0,0147	0,00154
Carcass meal	53,2	0,28	-0,0341	0,00390
Coconut oilcake (Copra meal)	18,8	0,27	-0,0143	0,00213
Cottonseed oilcake	40,2	0,22	-0,0341	0,00340
Fish meal (Chile)	71,3	0,53	-0,0090	0,00080
Fish meal (local)	71,2	0,29	-0,0097	0,00157
Groundnut oilcake	47,5	0,46	-0,1284	0,00547
Lupin	35,5	0,53	-0,1206	0,00851
Maize gluten 20	24,5	0,62	-0,0610	0,00599
Maize gluten 60	62,5	0,10	-0,0148	0,00209
Poultry byproducts (feathers and offal)	64,8	0,43	-0,0284	0,00674
Poultry litter	21,8	0,76	-0,0582	0,01167
Soybean oilcake	44,1	0,10	-0,0679	0,00338
Soybean meal fullfat roasted	40,0	0,21	-0,0318	0,00208
Soybean meal unheated	34,9	0,28	-0,0909	0,00831
Sunflower oilcake	40,3	0,46	-0,1461	0,01989
Waste water biomass (β radiated)	30,1	0,39	-0,0335	0,00529
Whole cottonseed	17,6	0,55	-0,1224	0,00522
Whole sunflower seed	18,8	0,67	-0,1499	0,01024

[e] Standard error for rate of N disappearance

stainless steel disc (135 g, 8 cm diameter, 2,5 mm thick) with 10 evenly spaced small holes drilled through the periphery of the disc. The disc was tied to a 700 mm nylon string which was secured at the rumen cannula. Using the complete exchange method (Paine, Crawshaw & Barber, 1981), one bag per test protein was placed in the rumen of each of the four cows for every incubation period. This procedure was repeated twice, giving a total of eight observations for each variable studied. At each incubation period (1, 2, 4, 6, 8, 12 and 24 h respectively) only one disc (10 bags) was incubated per cow in order to prevent interaction between bags. At the end of each incubation period all the bags were removed from the rumen, rinsed under running tap water (15 seconds) and washed in a washing machine (cold water) for 10 min. An additional eight bags per feedstuff were subjected to the washing procedure outlined above, and used for 0-h values. The washed nylon bags were dried in a forced draught oven at 65°C for 48 h. A bag containing 5 g cottonseed oilcake was used as a control feed during each incubation to monitor day to day variation in rumen function. Cottonseed oilcake was chosen because it exhibits a linear rate of dry matter (DM) disappearance over extended time intervals (Nocek, 1985). Protein sources were retested if DM disappearance varied more than 10% from established disappearance curves (Nocek, 1985). Differences between days, however, were minimal.

Contents of the bags were removed after incubation and subjected to Kjeldahl N analysis (AOAC, 1975). The percentage disappearance of N at each incubation time was calculated from the proportion remaining after incubation in the rumen. The rate constant for the degradation of N in the bags (*Kd*) was calculated from the slope of the natural logarithm of the N remaining in the nylon bag vs time. The extent of degradation of the feed protein in the rumen (*dg*) was estimated using the formula of Miller (1980)

$$dg = a + (1 - a)\frac{Kd}{Kr - Kd}$$

where a = fraction of N disappearing from the nylon bag at zero time (assumed soluble and 100% degraded) and Kr = rate constant for passage of undegraded protein from the rumen.

Fractional outflow rates of 0,02; 0,05 and 0,08 were used in the calculations. In a recent study the *in vivo* protein degradation of 34 diets were measured and among others, compared to the values obtained by the method of Miller (1980) calculated at a fractional outflow rate of 0,06. On average the method of Miller (1980) underestimated the protein degradability by only 1% (Stern & Satter, 1984).

Results and Discussion

The rate of N disappearance (K_d), fraction of N disappearance at zero time (a), and standard error for K_d are shown in Table 2. Animal products of low degradability such as fish meal and blood meal had much lower rates of N disappearance when compared to oilcakes of high degradability such as sunflower- and groundnut oilcake. The same tendency was found when the zero values were compared. Heat-treated protein sources like soybean oilcake and roasted soybean meal exhibited a lower soluble N fraction than did unheated soybean meal, as shown in Table 2. Rooke, Brookes & Armstrong (1983) also observed significantly higher K_d and 0-h values for untreated rapeseed- and soybean meal when compared to formaldehyde-treated meals. However, formaldehyde treatment may not be acceptable to render soybean meal undegradable in the rumen since it has been shown to decrease lysine and tyrosine availability (Erfle, Sauer, Mahadevan & Teather, 1986). Furthermore formaldehyde treatment of supplemental protein and other feeds probably will not become common practice because of potential human health hazards associated with the use of formaldehyde (Lundquist, Otterby & Linn, 1986).

It is important to correct for different outflow rates from the rumen to determine the effective protein degradability as the outflow rate may have pronounced effects on the degradation of most protein supplements in the rumen (Eliman & Ørskov, 1984). It is suggested that for practical purposes degradability values should be given in feed tables for three fractional outflow rates of small particles, namely 0,02/h for cattle given a low intake of mixed diets or completely ground diets; 0,05/h for calves and low-yielding dairy cows (fed energy at <

Table 3 Protein degradability values calculated at different fractional outflow rates

Feedstuff	Degradability calculated at different fractional outflow rates (K_r) 0,02	0,05	0,08
Blood meal	32,2	25,1	23,0
Brewers dried grains (sorghum)	47,6	29,7	23,2
Carcass meal	73,4	57,2	49,5
Coconut oilcake (Copra meal)	57,3	43,1	37,9
Cottonseed oilcake[a]	72,0	54,5	45,9
Fish meal (Chile)	67,5	60,0	57,6
Fish meal (local)	52,0	40,3	36,4
Groundnut oilcake	92,5	84,5	78,7
Lupin	93,4	86,4	81,5
Maize gluten 20	90,8	83,3	78,9
Maize gluten 60	48,6	31,0	24,5
Poultry byproducts (feathers and offal)	76,3	63,6	57,8
Poultry litter	93,5	88,2	85,3
Soybean oilcake	79,5	61,9	51,4
Soybean meal fullfat roasted	69,5	51,7	43,5
Soybean meal unheated	86,9	74,2	66,0
Sunflower oilcake[a]	93,5	86,2	80,9
Waste water biomass (β radiated)	77,2	63,5	57,1
Whole cottonseed	93,6	86,9	82,1
Whole sunflower seed	96,2	91,9	88,7

[a] The average protein degradability (24 observations) ± *SD* were 54,5% (± 1,9) for cottonseed and 86,2% (± 2,1) for sunflower oilcake. The samples were obtained from three different feed companies

Table 4 Relationship of UDP content in selected feedstuffs to cost relative to cottonseed oilcake (CSOM)[a]

Feedstuff	UDP, DM basis CP (%)	(%)	Relative to CSOM[b]	Cost Price R/ton	R/ kgCP	R/ kgUDP	Relative to CSOM[c]
Carcass meal	53,2	22,8	124	645	1,21	2,82	135
Cottonseed oilcake	40,2	18,3	100	380	0,95	2,09	100
Fish meal (local)	71,3	42,5	232	854	1,19	1,99	95
Groundnut oilcake	47,5	7,36	40	395	0,83	5,35	256
Maize gluten 20	24,5	4,09	22	263	1,07	6,41	307
Maize gluten 60	62,5	33,5	183	652	1,04	1,94	93
Soybean oilcake	44,1	16,8	92	535	1,21	3,17	152
Sunflower oilcake	44,1	6,08	33	375	0,85	6,16	295

[a] Calculations are based on the use of these feedstuffs as UDP sources and do not take into account their contribution to RDP. Similarly, differences in intestinal availability of UDP are not used in calculations. Therefore, the relative value based on UDP content would apply in a situation where RDP is adequate and UDP limiting

[b] UDP supplied per unit of the protein source relative to UDP supplied by CSOM

[c] Cost of protein sources (relative to CSOM) on the basis of UDP content

× maintenance ≡ yield of < 15 kg/d for a Friesian) and 0,08/h for high yielding dairy cows (fed energy at > 2 × maintenance ≡ yield of > 15 kg/d for a Friesian) given mixed diets (ARC, 1984).

Protein degradability values calculated in this study at the above-mentioned outflow rates, are presented in Table 3. The degradability values ranged from 25,1% (0,05/h) for blood meal to 91,9% (0,05/h) for whole sunflower seed. The percentage UDP in each of these feedstuffs is calculated as 100 — rumen degradability (RDP)%. Fish meal, blood meal, brewers grains and maize gluten 60 had high concentrations of UDP while feedstuffs like lupin, poultry litter, maize gluten 20 and the whole oilseeds were relatively poor sources of UDP. Considering oilcakes, coconut-, cottonseed- and soybean oilcake were by far superior to groundnut- and sunflower oilcake.

The value of fish meal for feeding dairy cattle is largely due to its relatively low degradability and the excellent amino acid profile when compared to most vegetable protein sources (Chancellor, 1983). From Table 3 it is clear that different batches of fish meal differ markedly in their UDP value, resulting in important economic implications. Mehrez, Ørskov & Opstvedt (1980) have shown that the processing method can have a pronounced effect on degradability and can alter its value by more than 50 percentage units. It is therefore of great importance to evaluate expensive protein sources such as fish meal before purchasing large quantities. Because of the variation in degradability within feeds (different varieties and processing methods), care must be exercised when using degradability figures as some overlap could be expected.

It does not seem necessary to investigate the effect of processing (apart from formaldehyde and excessive heat treatment) on oilcakes as three samples of each of cottonseed- and sunflower oilcake were obtained from different feed companies and the protein degradability calculated. The average protein degradability at a fractional outflow rate of 0,05/h (24 observations) ± *SD* were 54,5% (± 1,9) for cottonseed oilcake and 86,2% (± 2,1) for sunflower oilcake respectively. It is therefore clear that factors such as dry matter intake and fractional outflow rate exert by far a greater effect on the protein degradability.

When some of the feedstuffs evaluated in this study were rated on a cost per kg CP basis, groundnut oilcake was the least expensive and carcass meal the most expensive (Table 4). However, on a cost per kg UDP basis maize gluten 60 and fish meal were the least expensive and maize gluten 20 and sunflower oilcake the most expensive. There was a much greater price difference between feedstuffs in cost/kg UDP (R1,94 – R6,41) than in cost/kg CP (R0,83 – R2,21). The same tendency was found by Kennelly, Murphy & de Boer (1986). It is also important to remember that calculations based on UDP content of these protein sources do not take into account their contribution to RDP and consequently would only apply to situations where dietary RDP is adequate and UDP is limiting. In dairy cattle diets, UDP is frequently a limiting factor during

early and mid lactation while RDP tends to be adequate or excessive (Kennelly *et al.*, 1986).

For the lactating dairy cow to reach her production potential the diet must be composed of sufficient RDP to satisfy the needs of microbial fermentation in the rumen and sufficient UDP to escape rumen fermentation to supply additional amino acids to the lower gastro-intestinal tract. Only then will protein reserves be elevated for the enhancement of milk production (Crish, Wohlt & Evans, 1986). Unfortunately the minimum amount or ratio of RDP to UDP needed to maximize dry matter intake and milk production are still unknown (Chalupa, 1984; Waldo & Glenn, 1984). Although RDP and UDP requirements at different production levels were published (ARC, 1980; 1984) it was found in field situations that unexpected and variable responses to diets with enhanced UDP levels occur, even when dietary UDP levels are calculated to be in excess of the ARC recommendations. The variable results may be caused by differences in rate of passage out of the rumen, differences in intestinal digestibility or differences in amino acid profile not taken into account in field trials. This indicates the necessity to use a UDP safety factor in estimating the quantity of UDP required in the diet of high-yielding dairy cows (Twigge & van Gils, 1984).

Waldo & Glenn (1984) compared 10 protein systems by calculating the minimum dietary protein recommended by each system when the supply of undegraded protein intake was optimized. Predicted minimum protein in dietary dry matter ranged from 9 – 13% at 10 kg milk/day and 11 – 17% at 40 kg milk/day. The predicted optimum for undegraded protein intake ranged from 7 – 41% at 10 kg milk/day and 20 – 55% at 40 kg milk/day. Such extreme differences in the final recommendations of the systems must be a cause for concern (Satter, 1986). However, to deny or abandon the new insights and concepts on protein utilization is irresponsible. There are some ways of putting new information about protein utilization by dairy cattle into practice without necessarily employing a whole protein system that is not ready for full field application (Satter, 1986).

Conclusion

The following guidelines can be given concerning diet formulation for lactating dairy cows: An ideal dairy cow feeding system should combine a good source of UDP for direct utilization by the cow together with a source of NPN or highly degradable protein (RDP) to supply the required ammonia N for optimal rumen microbial growth (Stallings, Armentano & Polan, 1983; Erfle, *et al.*, 1986). Ensiled products such as silages contain a relatively high proportion of RDP. Therefore it is best to use poorly degradable feed ingredients to complement ensiled feeds. This can be done with the use of heated soybean meal, fish meal or other good sources of UDP. Highly degradable oilcakes like sunflower and groundnut should not be fed with urea but rather with low degradable sources such as fish meal or gluten 60. The inclusion of urea in diets containing lupins is not recommended (Muirhead, 1987), while a combination of urea, fish meal and cottonseed oilcake is a good combination of protein sources (Erasmus, de Bruin, Grové, Neitz & Meissner, 1986). The best way to put this information into practice is to use the protein degradability tables and to make judgements about the relative amount of bypass protein in a diet and it is important to provide enough of both RDP and UDP.

An irregular supply of carbohydrates to the rumen is also likely to result in a reduced level of microbial protein synthesis and a corresponding increase in UDP requirement. Compounds which are high in rapidly fermentable starch and sugars (barley, wheat, molasses, etc.) and fed twice daily may warrant greater quantities of UDP than where such diets are fed in smaller quantities with greater frequency. Highly degradable concentrates (usually containing NPN), if used, should be added to complete diets provided there is a readily available source of energy such as maize (Twigge & van Gils, 1984).

The lower degradability obtained at higher outflow rates implies that less N is available for the rumen micro-organisms, The lower rumen degradability could result in a deficiency of RDP for the microbes which would then have to be corrected for by addition of urea or other sources of degradable N. This is illustrated in a study conducted by Oldham, Napper, Smith & Fulford (1985) where a concentrate containing a combination of 1,6% urea and 4% fish meal gave similar results to a concentrate containing no highly degradable N source but 12,1% fish meal.

As various factors affect protein degradability, the optimum ratio of RDP : UDP is not fixed (Wilson & Brigstocke, 1983). The approach of Preston (1986) is as follows: If the CP level in the final diet exceeds 10% of the DM, all CP above this amount should be bypass protein. In other words, if the final diet contains 16% CP, 6% of the 16% or 37,5% of the CP should be in the form of bypass protein. Once these relationships are quantified better, CP requirements, especially at higher protein levels may be lowered.

Pricing of protein sources on the basis of UDP content rather than CP has a major impact on the relative value of feedstuffs. When the UDP content of a diet is limiting, a price system based on the content of UDP reflects the true feeding value of a protein source more accurately than does its CP content (Kennelly, *et al.*, 1986). A prerequisite, however, is that the UDP must be intestinally degradable.

Although the amount of UDP entering the small intestine is normally a small fraction compared to microbial protein, its digestibility is important to the supply of amino acids to high-producing animals. Hvelplund (1985) showed that the digestibility of N in the small intestine varied between 0,63 and 0,86 for the seven feedstuffs tested. It is therefore necessary to distinguish between different feedstuffs in respect of digestibility of UDP in the small intestine. As data become available it will be possible to adjust the relative

values of these feedstuffs to reflect UDP availability (Kennelly, *et al.*, 1986).

Finally, in the search for resistant protein sources to supplement diets of high-producing dairy cattle, protein quality must not be overlooked (Satter, 1983). The amino acid composition of the feed protein, when this is selected or protected to bypass the rumen, is a factor which must be considered, as this can have a major effect on the amino acids available for productive purposes (Hvelplund, 1986). The results from a recent study by Crooker, Clark, Shanks & Hatfield (1986) demonstrated that the amino acid profile of soybean meal does change due to ruminal degradation. The changes that may occur in the amino acid profile of UDP is a definite area for further research and is an important aspect to consider together with protein degradability when feedstuffs are selected to formulate diets for high-producing dairy cattle.

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