Milk Yield and Its Fat Content as Affected by Dietary Factors: A-Rewiew

R. K. Sawal and C. K. Kurar
Dairy Cattle Nutrition Division, National Dairy Research Institute, Karnal-132 001, India

ABSTRACT: Milk yield and its composition is governed by level of nutrition and the composition of diet. Higher concentrate input improves milk yield, whereas its input at moderate levels improves yield of milk fat. High level of dietary protein improves dry matter intake and milk production, however, CP content above 14% has less advantage. Milk yield is enhanced by the feeding of cottonseed and soyabean meal, whereas milk fat increases by the supplementation of cottonseed. Dietary fat increases energy intake, production of milk and milk fat. Quality and quantity of feeds consumed affect fermentation patterns in rumen. Among the rumen metabolites, volatile fatty acids (VFA) content and propionate proportion have been related positively with milk yield, whereas proportion of acetate and butyrate have been related positively with milk fat content. Dietary carbohydrates through the source of sugar, starch, roughage and fibre affect VFA concentration in rumen. Therefore, concentration of volatile fatty acids could be altered to the advantage of consumer through judicious manipulation of diet.

(Key Words: Concentrate: Roughage Ratio, Total Volatile Fatty Acids, Acetic Acid: Propionic Acid, (Acetic Acid + Butyric Acid)/Propionic Acid, Milk Yield, Milk Fat)

INTRODUCTION

There are various factors which affect the milk yield and fat content. However, the dietary factors which influence the most, include plane of nutrition, concentrate to roughage ratio, level and source of protein, fat, fibre and structure of diet (Jelec, 1990). Different feeds result in variable type of fermentation in the rumen. Most important effect is seen on the volatile fatty acids (VFAs) concentration and their proportions. From the review of literature, it became apparent that higher the concentration of VFAs, higher is the milk yield. Not only this, higher the propionic acid proportion higher is the milk yield and higher the proportion of acetate and butyrate, higher the fat. Therefore, this review covers the literature on feed and related factors which affect the milk and milk fat yield.

FACTORS GOVERNING YIELD AND MILK COMPOSITION

Concentrate : roughage ratio

Adequate nutrition is important for milk production, however, potential of a cow can favourably be exploited at high planes of nutrition (Altman, 1980). Intake of concentrate ranges between 0.16 to 0.36 kg DM/kg milk and this could influence assessment of response (Bines, 1979). Increase in intake of concentrate increases total feed intake, increases milk, however, decreases milk fat content (Oldenbrock, 1979). Long term feeding experiments (table 1) with silage as sole roughage also indicated increase in milk with higher input of concentrate, whereas higher milk fat was observed when fed concentrate at moderate levels.

Table 1. Effect of concentrate level on performance of dairy cows for 21 years

Feed intake Concentrate	(kg DMT/d) Silage	C/R* ratio	MY (kg/d)	Milk fat (g/kg)	Reference
2.2	10.3	0.18	15.9	36.1	Laird et al. (1981)
4.7	9.2	0.34	18.0	38.0	
7.6	6.9	0.52	20.8	36.1	

* Calculated values, MY: milk yield.

[1] Address reprint requests to C. K. Kurar.

Received June 24, 1997; Accepted December 1, 1997

Higher level of milk is obtained with higher input of concentrate with straws and hays as roughage (table 2), though better effects are observed with good quality hay. Milk fat content has been observed to follow reverse trend with higher input of concentrate. Nil effect on yield and milk fat content have also been recorded (Halevi et al., 1973).

Diets containing maize sustained more milk than barley as grain supplement at moderate levels of concentrate input, whereas at higher levels, barley proved to be a better substitute as it also improved milk fat content (table 2).

On feeding rations in separate and mixed forms, yield as well as milk fat content were not affected when fed concentrate and roughage in equal proportion (table 2). However, milk fat content improved on feeding concentrate at higher level in mixed diet. (Phipps et al., 1984).

Table 2. Effect of concentrate to roughage ratio on milk yield and milk fat content

C/R ratio	MY (kg)	FCM (kg)	Milk fat (%)	Constitution of diet	Reference
0.50	10.9	11.7	4.46	wheat straw as	Patel & Sharma (1983)
0.65	11.8	12.4	4.41	roughage	
0.55	13.3	11.6	3.19	wheat straw as	Halevi et al. (1973)
0.70	13.7	11.9	3.10	roughage	
0.85	13.5	11.4	2.99		
0.525	19.1	17.2	3.32	wheat straw as	Blair et al. (1974)
0.675	20.1	17.0	2.93	roughage	
0.825	20.3	15.6	2.51		
0.25		12.98		low quality meadow	Akkan & Ozkan (1987)
0.50		14.35		hay as roughage	
0.75		12.05			
0.50	30.4	25.9	3.02	good quality hay	Amir (1974)
0.80	30.5	24.0	2.61		
0.67	30.5		3.60	high quality alfalfa	De Peters & Kesler
0.80	31.3		3.40	hay as roughage	(1980)
1.00	32.3		3.40		
0.40	20.4		3.50	maize based	Flatt et al. (1969)
0.60	20.9		3.00	conc. mix.	
0.80	18.1		2.70		
0.60	16.9		3.88	barley based	Broster et al. (1979)
0.75	20.8		3.54	conc. mix.	
0.90	22.8		2.71		
0.60	16.1		4.49	Cereal rolled barley	Sutton et al. (1980)
0.90	20.6		2.06	in conc. mix.	
0.60	18.9		4.04	Cereal ground maize	
0.90	15.6		2.97	in conc. mix.	
0.50	24.2		4.01	Separate diet.	Phipps et al. (1984)
0.65	22.1		3.16		
0.50	23.6		4.07	mixed diet	
0.65	22.2		3.92		

C/R – Concentrate: Roughage, MY - milk yield, FCM - Fat corrected milk.

Feeding restricted roughage and high concentrate diet reduced butter fat percent (Van Soest and Allen, 1959), whereas it increased with decrease in concentrate proportion even at similar DE intake (Broster et al., 1979). Reduction in butter fat is more when concentrate proportion increases above 60 percent (Moe and Tyrrell, 1975) with no significant increase in milk production (Brown et al., 1977). Higher milk fat is observed with diets high in roughage due to higher acetate/propionate (A/P) ratio, whilst reduction in A/P ratio on concentrate rich diets produce less fat milk (Banks et al., 1983). A/P ratio and milk fat (Tyrrell, 1980) and milk production (Ronning and Laben, 1966) were highest with rations containing 40 percent concentrate. There is no single proportion which can be recommended for maintaining milk fat content; though higher the feed intake, higher the fibre content necessary to maintain milk fat content (Sutton, 1981).

Response in milk output to higher input of concentrate declines as the lactation advances, since progressively more energy is partitioned into body weight gain and less to milk (Broster and Thomas, 1981). Thus, higher efficiency of conversion of feed to milk could be achieved when cow maintains the body weight during the lactation. High intake of feed and above average milk production can be achieved when ration contains 50 to 60 percent concentrate and 40 to 50 percent roughage (Moe and Tyrrell, 1975).

Total volatile fatty acid (VFA) content increases with increase in proportion of concentrate (table 3), the effect being quite consistent with good quality hays, silages and green fodders, however, it is less affected with wheat straw as roughage. Sole oat fodder supported higher VFA content than concentrate containing diets (Soni and Sharma, 1982). Acetate predominates on high roughage diets, feeding of high concentrate diets increases molar proportion of propionate and butyrate (Van Soest and Allen, 1959; Banks et al., 1983) whereas acetate reduced propionate even with similar level of energy intake (Hogson and Thomas, 1975; Goetch and Galyean, 1982). Acetate proportion increased with incerase in straw content of diet, whereas butyrate remained unaffected (Halevi et al., 1973). By increasing concentrate in diet acetate proportion is not necessarily altered, instead propionate production increases, thereby altering A/P ratio (Bauman et al., 1971). A/P ratio is influenced by type and quality of forage (Wagsness and Mullar, 1981). Higher A/P ratios were observed between 40:60 (Tyrrell, 1980) and 50:50 (Akkan and Ozkan, 1987) concentrate : roughage ratio depending upon quality of roughage and constitution of diet. Calculated values (table 3) indicate that postulated

Table 3. Effect of concentrate to roughage ratio on VFA concentration

C/R ratio	TVFA (mM/L)	A/P*	(A+B)*/P	Constitution of diet	Reference
0.55		3.8	4.4	wheat straw as roughage	Halevi et al. (1973)
0.70		3.7	4.2		
0.85		3.0	3.6		
0.25	83.5	3.6	4.2	wheat straw as roughage	Goetch & Galyean (1982)
0.75	79.1	3.1	3.7		
0.00	39.0			rice straw as roughage	Manget Ram et al. (1985)
0.30	90.0				
0.70	113.0				
1.00	126.0				
0.67	88.9	3.0	3.7	good quality alfalfa	De Peters & Kesler (1980)
0.80	100.6	3.0	3.7	hay as roughage	
1.00	105.1	2.7	3.4		
0.15	78.0	2.7	3.5	pearl millet silage and rye grass	Chauhan et al. (1994)
0.25	84.5	2.3	2.7	hay as roughage	
0.50	98.4	1.8	2.5		
0.60		2.8	3.3	rolled barley based diet	Sutton et al. (1980)
0.90		1.0	1.3	ground maize based diet	
0.60		3.0	3.6		
0.90		1.9	2.3		

* Calculated values; TVFA – Total VFAs.

(acetate + butyrate)/propionate (A+B)/P ratio increases with incerase in roughage proportion in diet, however, this also accounts for contribution of butyrate towards milk fat. (A+B)/P values near or above four have been recorded with diets containing 50 to 60 percent roughage as fodder or 30 to 40 percent straw. Infusion studies indicate positive relationship of milk yield with proportion of acetate, energy and protein content of diet. (table 4) and milk fat with acetate, butyrate and long chain fatty acids. Whereas, propionate and level of protein contribute towards SNF.

When concentrates are added to roughage based diet, it results in reduction in the dietary fibre starch ratio. The ruminal acetate propoionate ratio falls, resulting in a shift in substrates and in their utilization. There was milk fat depression (Sutton, 1976). Proportion of propionic acid increase when the roughage content of the diet was reduced with the reduction of acetic acid and butyric acid.

Table 4. Effects of change in supply of some metabolites on milk yield and composition

Product of digestion	Main site of absorption	Response to change in supply (% of control)			
		milk yield	fat content	protein content	lactose content
Acetate	Rumen[1]	+ 8.3	+ 8.9	− 1.2	+ 2.1
Propionate	Rumen[1]	− 1.6	− 8.3	+ 6.5	+ 0.8
Butyrate	Rumen[1]	− 4.9	+ 14.2	+ 2.2	+ 2.2
Glucose	Small intestine[2]	+ 5.5	− 10.3	− 1.1	+ 0.9
Amino acids	Small intestine[2]	+ 7.2	− 2.5	+ 5.9	+ 0.5
Long chain fatty acids	Small intestine[3]	+ 2.1	+ 13.1		

[1] Rook & Balch (1961), Rook et al. (1965) intra – ruminal infusions.
[2] Thomas & Chamberlain (1984) intra – abomosal infusions.
[3] Story et al. (1969a, b) intra – venous infusions.

The ration causing problems invariably produce a rapid fermentation in the rumen with increased yields of volatile fatty acids. Yield of all individual acids is increased but that of propionic acid and the branched chain fatty acids is increased more than the others. The proportion of propionic acid in the rumen fluid rises. Saturation of long chain fatty acids in the rumen is affected such that trans fatty acids are produced. Increase in the concentration of glucose, insulin and acetate in the circulation is observed. The cows often gain weight. Uptake of long chain fatty acids and acetate by the mammary gland is inhibited and the proportion of short chain to long chain fatty acids and acetate by the mamary gland is inhibited and proportion of short chain to long chain fatty acids in milk fat increases. It is probable that growth hormone concentration falls (Holmes et al., 1987).

Sutton et al. (1980) reported that on two barley based diets, 40 hay: 60 concentrates and 10 hay: 90 concentrates, there was decrease in the rate of production of acetic acid and butyric acid and increase in production of propionic acid on reducting hay: concentrate ratio. Balch (1971) indicated that increased propionic acid would stimulate the synthesis of milk protein. This was also reported by Rook (1961). Broster et al. (1977) reported fall in the milk fat content when the ratio of acetate and propionate in the rumen fell below 3:1.

Scientists over the past have worked with different concentrate roughage ratios and came to following conclusions. Elliot and Loosli (1959a) reported that 20, 40 and 60 percent of estimated ME from the grains had no significant effect on the milk yield. An all forage diets did not support the maximum yield; also diet of more than 25 percent grain have no effect on the milk production. Flatt et al. (1969) by their experiment showed that there was fall in the milk yield at ration containing 20 percent hay and 80 percent maize based concentrates diet when compared to ration containing 40 percent hay and 60 percent concentrates. Owen (1975, 1976) concluded that near 70:30 is an optimal concentrate hay ratio for the dairy cows. However, Ekern (1970) suggested 75:25 ratio of concentrates: hay for optimal milk production in the early lactation.

Broster et al. (1981) reported increase in milk yield by feeding a diet of concentrate: roughage in the ratio of 90:10 for both adult cows and first calf heifers. Mahal et al. (1997) fed three groups of crossbred cows with roughage concentrate ratio of 50:50, 60:40 and 70:30. The milk (4% FCM) production was significantly higher in group fed with 60:40 roughage concentrate ratio. However, no significant differences were observed between various treatment groups in respect of milk fat, total solids, solids-not-fat and protein content in milk. It was concluded from the studies that 60:40 roughage : concentrate ratio can be recommended for medium crossbred lactating cows.

Broster et al. (1979) and Sutton et al. (1980) showed by their experiments that when the ratio of hay to concentrates was reduced, the yield of lactose and protein or SNF were increased by 20 to 40 percent and milk fat content fell in both the experiments. In the experiment by Broster et al. (1979), the fall in milk fat content was due primarily to the increase in milk yield, whereas in the experiment by Sutton et al. (1980), it reflected the combined effects of an increase in milk yield and a decrease in fat secretion with the result that milk fat depression was particularly severe.

Reducing the roughgae : concentrate ratio in diets usually causes milk fat concentration to fall, but the pattern of response varies widely. However, fat concentration is fairly stable until proportion of roughage in the diet on a DM basis falls to about 50 percent, but with further reduction in the proportion of roughgae, variable decrease in milk fat concentration occur (Journet and Chilliard, 1985; Thomas and Martin, 1988). Broster et al. (1979) showed that milk fat content fell at each level of DE intake as the proportion of the concentrates was increased from 60 to 90 percent but that it also fell at each hay:concentrate ratio when level of DE intake was increased. The higher is the level of feed intake, higher the fibre content necessary to maintain a given fat content.

The diet effects on SNF content were generally very small. However, under-feeding of cows do cause SNF content to fall appreciably. On the other hand, over-feeding does not increase SNF content (Balch, 1972). Balch (1971) indicated that increased propionate would stimulate the synthesis of milk protein.

The relationship between milk fat concentration and dietary ADF concentration was linear over the range of between about 9 and 22 percent ADF in the DM covered in these experiments (Broster et al., 1985; Sutton et al., 1980, 1985b, 1987). Milk fat concentration fell by 0.17% unit per 1 percent unit decrease in dietary ADF concentration in the DM. The relationship would not be linear if higher concentrations of ADF were included and seems probable that about 22 percent ADF in the DM is the minimum concentration required to prevent fat depression with some reliability (Sutton, 1985).

Dietary protein and milk yield

High content of VFA was observed on high plane of protein nutrition (table 5), whereas molar proportion of VFA remained unaffected. Increase in milk production is accompanied with increase in CP content of diet (Clarke and Davis, 1980) with positive and linear response in ascending order from 13.5 to 16.5 percent accompanied by increase in milk fat on diets containing cottonseed (Van Horn et al., 1979), 17.5 percent (Grings et al., 1991), 18 percent (Grieve et al., 1974) and 20 percent (Roffler et al., 1986). FCM yields were reported to be higher with 125 percent CP (Morely, 1970), and also with 110 percent CP and 130 percent energy (Patle, 1973). Maximum response of intake of 85 g CP/kg FCM has been speculated (Oldham, 1984). Increasing CP content of diet above 14 percent resulted in small but declining rate of increase in milk (Moe and Tyrrell, 1975) with little benefit above 17.5 percent (Grings et al., 1991). Reports thus reveal that maximum responses are achieved around 14 percent level of dietary CP.

Much of the response is due to effects on ration digestibility and increase in DMI (Oldham, 1984; Roffler et al., 1986). High producing cows require protein in excess of that available from rumen microbial protein synthesis (Orskov and Reid, 1985). Thus, it is reasonable to assume that high protein supply could alter milk production.

Table 5. Effect of protein content of concentrate on VFA concentration

Protein content (%)	TVFA (mM/1)	A/P*	(A+B)*/P	Reference
17.7	61.6	3.7	4.2	Verma et al. (1975)
26.7	67.2	3.9	4.5	

* Calculated values.

Protein supplements

Cottonseed increased milk fat (Coppock et al., 1987) though milk yield was not affected either on isocaloric diets (Moody and Cook, 1961; Stanely et al., 1969) or containing different levels of hay (Moody and Barnes, 1966). Milk fat content has been observed to increase when cotton seed was incorporated upto 20 percent (De Peters et al., 1985), 25 percent (Perry and Mc leod, 1968; Smith et al., 1981) level without affecting milk yield (table 6). Cottonseed increased milk fat though milk production was similar to groundnut cake, but it was lower than soyabean meal due to low DM digestibility of cottonseed (Van Horn et al., 1979). When whole cottonseed up to 24.8 percent in ration was fed to milch cattle, fairly constant increase in milk yield and fat content was observed (Van Horn et al., 1979).

Daily yield of milk and fat content increased with increase in dietary CP from 13.8 to 17.5 percent with cottonseed supplement, beyond it, it showed little benefit in milk yield (Grings et al., 1991). The increase in milk energy output attributes to increase in long chain fatty acids synthesized in the mammary gland and decrease in milk protein due to feeding whole cottonseed (De Peters et al., 1985). Cottonseed when fed alongwith molasses improved milk yield without affecting milk fat content (Kakkar and Mudgal, 1981). When fed different forms of cottonseed supplements, higher milk yield was recorded for undecorticated cottonseed cake and higher milk fat on feeding cottonseed (Kakkar and Mudgal, 1979a, b). However, both yield and fat content of milk improved by incorporation of whole cotton seed up to 20-25 percent in the diet (table 6). Milk yield and fat content were found to be similar on diets containing cottonseed or soyabean (Mohamed et al., 1988).

Whole cottonseed had no determinental effect on rumen function (Smith et al., 1981). Similar VFA levels were observed when cottonseed was incorporated either as solvent extracted, expeller crushed or expeller crushed undecorticated compared to groundunt cake in concentrate diets (Sood, 1982). However, VFA content and proportion of propionate as well reduced on feeding cottonseed cake (table 7) as indicated by the A/P and (A+B)/P ratio. Higher acetate was observed at 15 and 30 percent incorporation, whereas propionate reduced with increasing input of whole cottonseed (Horner et al., 1988). VFA concentration was found to be similar on rations containing either cottonseed cake or mustard cake (Yadav and Bhatia, 1992).

Table 6. Effect of level of protein supplement on milk yield and milk fat content

Protein supplement	MY (kg)	FCM (kg)	Milk fat (%)	Feed Supplement	Reference
Solvent extracted					
5% CC	9.8	9.7	3.93	barley, GN, WB,	Chaturvedi (1992)
10% CC	9.9	9.8	4.01	green maize, WS	
15% CC	10.1	10.5	4.27		
Con	5.9	6.8	5.09	conc. mix., green	Kakkar & Mudgal (1979b)
57% CS	6.2	7.4	5.40	fodder (maize/lucerne)	
44% CC U	6.9	7.8	4.98		
27% CC D	6.2	7.2	5.23		
Con	23.1	21.5	3.56	maize, barley, SB	Belibasakis & Tsirgogianni
20% CS	25.1	25.0	3.98		(1995)
Con	20.8		3.95	whole cotton seed	Smith et al. (1981)
5% CS	19.4		3.90		
15% CS	21.6		4.29		
25% CS	21.2		4.52		
Con + SS oil	24.5	17.7	2.16	barley, SB, wheat,	White et al. (1987)
9% SS	24.8	20.0	2.70	corn silage, WS	
15.5% SBM	18.0		3.44	corn silage as	Erfle et al. (1983)
33.5% SBM	19.5		3.97	roughage	
26.0% FM	16.1		3.39		
24% SBM	22.8	21.1	3.56	corn silage, barley,	Waldern (1973)
27% RM	22.0	18.9	3.10	molasses, mill run	
18% RM in starchy conc	27.5	29.4	4.48	oat, barley, wet distillery	Huhtanen et al. (1995)
18% RM in fibrous conc	26.6	27.7	4.27	solubles, by products	

RM – Rape seed meal; SBM – Soyabean meal; FM – Fish meal; WB – Wheat bran; GN – Groundnut cake; CC – Cotton seed cake; U – Undecorticated; D – Decorticated; CS – Cotton seed; SS – Sunflower seed; Con – Control; WS – Wheat straw; conc. mix. – Concentrate mixture.

Addition of crushed soyabean increased milk fat (Perry and Mc Leod, 1968; Banks et al., 1980). Diets containing soyabean meal increased the milk yield, whereas milk fat remained unaffected (Steele et al., 1971), or elicited no positive response on yield as well as milk fat content (Pachauri and Negi, 1978). However, higher milk fat has been reported with soyabean meal (table 6) compared to fish meal (Erfle et al., 1983).

Relative proportion of propionate increased and butyrate decreased, whereas, VFA content remained unaffected by addition of crushed soyabean meal (Perry and Mc Leod, 1968; Steele et al., 1971) or soyabean or soyabean meal (Srivastava and Mani, 1991; table 7). Volatile fatty acid levels were reported to be higher with soyabean meal than fish meal, whereas A/P and (A+B)/P ratio were observed to be higher with fish meal (Erfle et al., 1983).

Diets containing rapeseed meal sustained lower milk than those on soyabean meal, however, inclusion of rapeseed meal increased yield and fat content of milk (table 6) on starchy rather than fibrous concentrate (Huhtanen et al., 1995). Yield and fat percent increased by inclusion of whole sunflower seed (White et al., 1987) and maize gluten (Staples et al., 1984; Ohajuruka and Palmquist, 1989). High milk fat yields were obtained on feeding oil of unextracted seeds than free oil supplements (Steele et al., 1971; Anderson et al., 1979).

Volatile fatty acid content and molar proportion were unaffected by incorporation of sunflower seed (table 7) in concentrate (White et al., 1987). Higher VFA levels were observed when vegetable protein supplements (groundnut cake) were fed along with molasses compared to NPN as urea (Mudgal and Puri, 1977). VFA content was observed to be similar on diets containing different levels of groundnut cake (table 7), however, molar proportions of VFA varied, thus it is reasonable to assume that VFA content is governed more by the form and content of carbohydrate rather than kind of protein supplement in ration.

Table 7. Effect of protein supplements on VFA concentration

Protein supplement	TVFA (mM/l)	A/P*	(A+B)*/P	Feed supplement	Reference
Con	107.6	2.8	3.2	conc. mix. WS	Chaturvedi (1992)
10.0% CC	100.3	3.0	3.4		
22.5% CC	90.0	3.2	3.7		
35.0% CC	87.5	3.3	3.8		
Con+SS oil	45.0			barley, SB, wheat,	White et al. (1987)
9% SS	45.5			corn, silage, WS	
15.5% SBM		2.3	2.6	corn silage	Erfle et al. (1983)
33.5% SBM		2.4	2.8		
26.0% FM		3.4	4.0		
28% SBM	92.0			conc. mix, green maize	Bhoot (1989)
40% SBM	112.0			barley, WB,	Srivastava & Mani (1991)
40% SB	110.4			MF, WS	
17% GN	81.3	3.6	4.0	maize, WB, WS	Garg (1989)
30% GN	70.9	2.3	2.8	maize, WB, WS	Sawal & Singh (1986)
30% GN	96.5			maize, WB, WS	Kumar (1989)
35% GN	88.5	3.3	4.1	barley, maize, starch, MF, WB	Kapoor (1989)
40% GN	115.2	2.6	3.0	barley, WB, RS	Puri (1988)
35% MC	103.7	4.0	4.5	conc. mix. WS	Tiwari & Yadava (1989)

* calculated valnes, Con – Control, MC – Mustard cake, SS – Sunflower seed, SBM – Soyabean meal, SB – Soyabean, FM – Fish meal, WB – Wheat bran, GN – Groundnut cake, CC – Cotton seed cake, WS – wheat straw, RS – Rice straw, MF – maize fodder.

Effect of rumen bypass protein in diet of animals on milk and milk composition

Lot of literature was reviewed by Orskov et al. (1981a), Beever and Thomson (1981), Beever and Cottrill (1993). Therefore, it has become essential to cover the important aspects of rumen undegraded protein nutrition to cows and their effect on milk production and milk composition.

The protein requirement of the cows increases with the increase in milk yield. This is also because the net availability of amino acids from the feed and rumen microbial source as well is not sufficient. When the ME requirement of the cows are met fully than the protein deficiency does not occur. This has been summarised by Clark (1975). Cows which gave positive response to milk yield by casein infusion in the abomasum were in negative energy balance (Clark et al., 1973; Derrig et al., 1974). Orskov et al. (1977) reported that cows in early lactation responded by increasing their yield of milk when they are given protein supplements which largely escape rumen degradation but the cows were fed below their energy requirements. Similar observations were made when the cows were in negative energy balance and protected protein was fed to cows (Cressman et al., 1977; Verite and Journet, 1977; Roffler et al., 1978).

Recent work of Christensen et al. (1993) reported that milk production and 4 percent FCM was not altered by either CP intake or degradability of CP in the diet either during the first 49 d or the entire 20 week of the treatment period. The cows were fed diet ranging from 16. 4 to 19.4 percent CP that varied in calculated ruminal degradability of CP from 55 to 70 percent. The data suggested that either synthesis of milk and milk components was not limited by a shortage of amino acids or that the different dietary supplemental proteins did not alter amino acid availability.

Christensen et al. (1993) further reported that increasing the CP content of the diet and the proportion of undegradable CP in the diet increased non ammonia nitrogen flow to the duodenum. Except for methionine, flow of all amino acids to the duodenum were increased when CP was increased. Flow of methionine to the duodenum was not altered by undegradable CP content of the diet. No effect on production of milk and 4 percent FCM was observed by the amount of CP or undegradable CP. Milk fat and yield were increased when diets high in undegradable CP were fed. Results suggest that all diets supplied adequate amounts of amino acids for these cows or that methionine was deficient for all cows.

Kurar et al. (1996) with their studies on lactating crossbred cows and Murrah buffaloes fed with higher level of bypass protein and the concentrate mixture with lower content of bypass protein, revealed that 4 percent FCM yield was similar in both the groups of cows and buffaloes. There was no significant effect of treatment on milk yield. Orskov et al. (1981b) reported for the commercial herd with peak milk yields of 25 to 35 kg milk, the importance of feeding a protein resource of low degradability in early lactation has probably received unjustified emphasis, particularly in situation where the management of feeding is such that high intakes of total feed are achieved in early lactation.

Recent work of Wattiaux et al. (1994) suggests from their studies on lactating Holstein cows that the RUP recommendation as a percentage of either dietary DM or dietary CP might lead to a misinterpretation of the adequacy of a diet to support high milk yield. NRC (1989) predicts that the cows producing 40 kg of milk require 1.3 kg of RUP. In this trial there was no production response to increasing RUP intake above 1.3 kg/d and the cows met their requirement for absorbed protein without a source of supplemental protein resistant to ruminal degradation. Despite a high proportion of alfalfa silage in the diets, the carbohydrate status of the diets possibly played an important role in maximizing dry matter intake and bacterial protein yield from the rumen; thereby reducing the need for supplemental RUP source. At high dry matter intake the need for RUP supplementation might be lower than predicted by NRC (1989) because increased ruminal turn over rate enhances microbial protein yield from the rumen and RUP value of the diet by decreasing ruminal residence time.

Level of fat

The largest effects on secretion rates of milk constituents are caused by dietary fats and the form of carbohydrate; within normal limits dietary protein is much less important (Story, 1981). Increase in dietary fat improved milk fat content even on isocaloric diets. Transfer of dietary fatty acids to milk fat depends upon their dietary content, level of milk fat production and the metabolic equilibrium of adipose tissue as affected by stage of lactation and input of glucogenic nutrients (Story, 1981). Dietary fat may be included up to 3.5 percent level to lactation rations to increase energy intake of high producing cows or to reduce starch feeding, thereby, increasing forage proportion to prevent milk fat depression (Palmquist and Jenkins, 1980).

Source of dietary fat

When oil is provided in form of unextracted seeds higher milk fat yield are obtained compared to free oil supplements (Coppock and Wilks, 1991). Higher milk fat has been observed on feeding sunflower (White et al., 1987), soyabean (Anderson et al., 1979; Banks et al., 1980) and cottonseed (Kakkar and Mudgal, 1979b; Coppock et al., 1987; Belibasakis and Tsirgogianni, 1995). Oilseeds can be fed without observable ruminal inhibition probably because of slow release of oil into ruminal contents (Coppock and Wilks, 1991).

Level of dietary fibre

Pastures, cultivated fodders, agro-crop residues; the principal ruminant feeds are rich in dietary fibre. Molar proportion of acetate and propionate are closely related to content of dietary fibre (Elliot and Loosli, 1959b) of which acetate predominates with increasing proportion of dietary fibre (Jorgensen et al., 1965; Blaxter, 1967; Gordon and Forbes, 1971).

High forage diets produce more milk fat whereas those rich in concentrate produce less due to difference in fermentation patterns (Banks et al., 1983). Milk yield, however, reduce with increase in fibre level (Norfeldt et al., 1950). Concentration of VFA and A/P ratio increased with dietary NDF (table 8), so is the case with increase in ADF through barley compared to maize, indicating barley with higher levels of fibre sustained higher VFA production than maize, secondly diets containing alfalfa hay had higher VFA and lower propionate proportion than corn silage.

Roughage in proper quantity and physical form is necessary to maintain normal milk fat (Davis and Brown, 1970). Milk yield decreased and fat content increased linearly with rise in NDF in the diet, whereas milk fat content is not affected with increasing proportion of fibre through wheat straw (table 8). It has been postulated that milk fat content is reduced by approx. 18 g/kg for each 10 percent reduction, below 22 to 25 percent ADF (Sutton, 1984). A minimum of 17 percent CF, 21 percent ADF and 28 percent NDF is recommended for lactating cow (NRC, 1989). Cattle do not consume sufficient energy to achieve maximum milk if ration fibre is maintained to maximize milk fat, thus pose problem of formulating rations (Stanley et al., 1969). Protein supplementation on high fibre diets have been reported to improve milk yield without live weight change (Lees et al., 1990).

Effect of straw supplementation

Higher VFA levels were observed when berseem was fed along with wheat straw (Abbou Akkada and El-Shazly, 1958; Sharma and Mudgal, 1975). Wheat straw when supplemented to rations containing either maize or sorghum fodder increased acetate and reduced propionate, whereas butyrate remained unaffected (Chander and Ludri,

Table 8. Effect of fibre level and roughage supplement on VFA content and milk production

Fibre level	C/R	TVFA (mM/L)	A/P*	(A+B)*/P	MY (Kg)	FCM (Kg)	Milk fat (%)	Roughage supplement	Reference
% CF									
20.2	0.55		3.8	4.4	13.3	11.6	3.19	wheat straw	Halevi et al.
14.7	0.70		3.7	4.2	13.7	11.9	3.10		(1973)
9.5	0.85		3.0	3.6	13.5	11.4	2.99		
% NDF	Forage maturity								
31	early	131.9	3.5	3.9	27.0	22.7	2.86	alfalfa hay cut at	Beauchemin
	mid	124.3	2.8	3.1	26.8	20.0	2.50	two stages of maturity	(1991)
34	early	147.6	4.0	4.5	26.8	23.2	3.08		
	mid	124.0	3.6	4.1	25.7	21.8	3.04		
37	early	147.3	4.8	5.4	25.0	22.8	3.30		
	mid	134.0	4.4	4.9	24.5	21.8	3.31		
% ADF	grain								
23.0	barley	147.0	3.6	4.3				alfalfa hay	Kung et al.
19.4	Corn	135.0	3.4	4.1					(1992)
21.6	barley	145.0	3.1	3.7				corn silage	
19.7	corn	120.0	2.8	3.2					

* Calculated values.

1979). Alfalfa hay sustained greater proportion of acetate and lower propionate than corn silage (Kung et al., 1992). Wheat straw when fed with either groundunt cake or cluster bean meal as maintenance rations (8-10% CP) produced more VFA than oat hay (Sangwan et al., 1987, 1990), whereas VFA was observed to be similar on rations containing either wheat straw or gram straw (Yadav and Bhatia, 1992).

Milk yield and its fat content increased with proportionate increase in wheat straw (table 2) in ration (Blair et al., 1974). Feeding of wheat straw along with green fodder proved to be economical for increasing milk fat compared to sodium acetate supplementation specially during winter months without affecting milk yield (table 9).

No effect on milk and FCM yield have also been observed on partial or equal replacement of maize fodder with wheat straw as roughage (Singh et al., 1985). High level of roughage increased milk fat more on higher dietary energy level (El – Gallard et al., 1988). Thus, straws can be advantageously used along with green fodders up to 20 to 30 percent proportion in the ration of milch cattle.

Table 9. Effect of wheat straw supplementation on yield and fat content of milk

Diet	MY (kg)	FCM (kg)	Milk fat (%)	Reference
Conc. mix. + maize & Sorgham fodder	9.9	9.4	3.82[a]	Ludri (1978)
Conc. mix. + maize & Sorgham fodder + 300 g sodium acetate	10.0	10.2	4.06[b]	
Conc. mix. + maize & Sorgham fodder + 2 kg wheat straw	9.9	9.9	4.03[b]	
Conc. mix. + berseem fodder	13.7	13.9	4.08[a]	Ludri (1979)
Conc. mix. + berseem fodder + 2 kg wheat straw	13.6	14.6	4.31[b]	

Level of energy and its supplements

High yielding cows respond to changes in energy, whereas stage of lactation has less effect on yield response to energy input. There is tendency in rise in milk fat with increasing intake of energy (Morely, 1970) even with high roughage diets (El Gallard et al., 1988), accompanied by increase in milk yield (Sivaiah and Mudgal, 1983). Butter fat increased with increase in roughage proportion (10-40%) on barley (Broster et al., 1979), maize (Flatt et al., 1969) or maize and barley based diets (Sutton et al., 1980).

Production of VFA was more with substrates containing barley and molasses than straw, though proportion of propionate was more on barley and that of butyric acid on molasses based feed mixtures (Punia and Sharma, 1985). Maize and sorghum are fermented slowly as 20 to 40 percent of their starch escape rumen fermentation, they tend to support higher A/P ratio (Balch, 1972; Sutton et al., 1980), VFA content was observed to be similar (table 10) on incorporation of moderate levels of either maize, barley or oat grain in equal proportions in concentrate diets. It is likely that at such levels, fermentation of starch and its flow to lower gut was similar due to which VFA production was not affected appreciably; however, (A + B)/P ratio was higher with oat grain indicating lower propionate production. Diets high in molasses lead to higher butyrate and low propionate. It is rapidly fermented in the rumen and when fed between 10 to 30 percent, causes no feeding problems (Leng and Preston, 1976).

Table 10. Effect of grain supplementation on VFA concentration in rumen

Grain	TVFA (mM/L)	A/P*	(A+B)*/P	Reference
40% Maize	108.1	2.9	3.4	Datta and Thakur(1992)
40% Barley	106.7	2.8	3.3	
40% Oat	105.9	3.6	4.1	

* Calculated values.

Barley based diets increase milk yield compared to maize (table 2) with increase in dietary concentrate (Sutton, 1985), whereas milk fat content is reduced (Broster et al., 1979; Sutton et al., 1980). Though replacement of barley with maize at moderate levels brings about no change in milk fat, yet there is improvement in milk yield (Martin, 1986; Mc Carty et al., 1987). Even on similar DE intake, fall in milk fat is less severe with maize than barley; maize suited better when concentrate formed 40 percent of diets for both milk and butter fat production (Flatt et al., 1969; Broster et al., 1979; Sutton et al., 1980). Maize and sorghum tend to support higher milk fat (Balch, 1972; Sutton et al., 1980). Higher FCM yield has been recorded with oats compared to barley or wheat (Moran, 1986).

Feed intake through concentrate reduced with increase in sugar plus starch content (table 11), though energy intake increased, but milk yield as well as milk fat content also reduced. Beet pulp supported higher FCM than starch containing rations (Petit and Trembley, 1995). Wet distillery solubles increased milk yield and fat content when given starchy concentrate diet (Huhtanen et al., 1995). Supplementation of molasses based product increased yield and milk fat content as well on rations containing rice straw than maize stover (Annis et al., 1991). Thus, rations containing soluble sugars along with cereal starch at low to moderate levels support higher production of milk and milk.

Table 11. Effect of content of sugar and starch on milk production

	Sugar + Starch content of concentrate (g/kg DM)				Reference
	217	308	440	516	
Feed intake (kg DM/d)					
Concentrate	11.2	10.4	9.3	8.3	De Vesser & De Groot (1980)
Roughage	7.4	7.4	7.5	7.5	
Total	18.6	17.7	16.8	15.8	
MY (kg/d)	32.0	31.0	30.3	27.7	
FCM (kg/d)	32.6	31.5	30.3	26.9	
Milk fat (g/kg)	41.5	41.2	40.3	38.9	

Effect of non structural carbohydrates in the ration of cows on milk yield and composition

The carbohydrate composition of the concentrates fed may also have effects on proportion of VFA produced (table 3) in the rumen. Common concentrate feeds are rich in starch, pectin, digestible cellulose, digestible hemicellulose and essentially sugars generally added in the form of molasses. Irrespective of forage supplement, milk production is not affected by the type of concentrate even up to moderate level of concentrate input (table 12). Cows given hay and concentrate diets containing 80 percent concentrates showed marked effects of 'fibrous' compared to 'starchy' concentrates on milk fat content and yield. However, smaller effects were observed with cows receiving lower proportion of concentrates with hay or silage as roughage supplement. (table 12). At higher

Table 12. The effects of carbohydrate composition of concentrate feed on milk yield and milk fat content

C/R ratio	Type of forage	Type of concentrate	MY (kg)	Milk fat (%)	Reference
0.80	hay	starchy	32.0	2.26	Sutton et al. (1985a)
		fibrous	25.5	3.62	
0.60	hay	starchy	26.3	4.15	Sutton et al. (1985a)
		fibrous	26.5	4.29	
0.64	silage	starchy	29.1	3.83	Thomas et al. (1984)
		fibrous *	30.1	3.93	
0.43	silage	starchy	24.6	4.63	Thomas et al. (1984)
		fibrous	26.7	4.05	
0.37	silage	starchy	19.9	4.63	Chamberlain et al. (1984)
		fibrous/sugar **	18.6	4.04	

* fibrous concentrates contain added fat.

** concentrates contained 360 g molasses DM kg^{-1} DM.

levels of concentrate input, higher milk fat yields with fibrous concentrates are observed, however, with increase in forage proportion, higher milk fat yields are observed with starchy compared to fibrous concentrates.

Broster et al. (1979) showed by their experiment on lactation on hay and barley based concentrates, the milk yield increased when the ratio of hay to concentrates was 10:90 also there was increase in the yields of lactose, protein and SNF, however, milk fat content fell.

Sutton et al. (1980) reported that when diets formed 10 percent hay and 90 percent rolled barley, there was increase in milk yield. However, milk fat content decreased in comparison to cows fed with ration containing 40 percent hay and 60 percent concentrates containing rolled barley.

Sutton et al. (1980) further reported that with low roughage diets, the size of milk fat depression caused by ground corn has been less than that occurring with rolled barley. Oats have been reported to cause lower milk fat concentration than barley in conventional diets (Martin and Thomas, 1988). In diets with adequate roughage, milk fat concentration is very similar with rolled barley or ground corn (De Peters and Taylor, 1985; Sutton et al., 1980).

Source of carbohydrates in the ration of cows is quite important. It was depicted by various workers that when the concentrates are based on rolled or ground barley or corn, the fall is rapid and often severe resulting in milk fat concentration below 2 percent in extreme cases (Balch et al., 1955; Broster et al., 1985; Sutton et al., 1980, 1985b; Sutton, 1989).

Efficiency of energy utilization

Efficiency of conversion of ME to milk is fairly constant when molar proportion of acetate ranges from 50 to 60 percent, however, lower and higher proportions depress milk fat content (Elliot and Loosli, 1959b). Further studies also reported better utilization when end products of fermentation favour acetate (Kay, 1972; Hovell and Greenhalgh, 1972). There is no variation in efficiency of ME utilization for milk production due to level of milk yield, stage of lactation, breed of animal. However, there is small variation due to composition of diet and composition of milk (Moe and Tyrrell, 1975). Type of carbohydrate and nitrogen included and nitrogen to energy ratio of ration influence milk production and feed efficiency (Clark and Davis, 1980). Efficiency for use of ME for milk averaged 60 percent for diets of 56.4 percent ME, it increased/decreased by one percent (Van Es et al., 1970). Scope for improving energetic efficiency of milk production by altering proportion of either of major VFAs exist for enhancing yield of milk along with fat content by changing composition of diet.

DISCUSSION

Potential of cow can be favourably exploited at high planes of nutrition, though both yield and fat content of milk are governed by composition of diet. High dietary protein supply alters milk production due to effects on ration digestibility and dry matter intake, whereas maximum responses are achieved around 14 percent dietary CP, above which there is small but declining rate of increase in milk. Dietary fat can be included up to 3.5 percent to increase energy intake. Unextracted oil seeds as cottonseed can be used up to 25 percent to increase both yield and fat content of milk, whereas higher milk yields can be obtained with soyabean meal as protein supplement. A minimum of 17 percent CF or 22 to 25 percent ADF or 28 percent NDF has been recommended below which there is depression in milk fat.

Fermentation patterns in rumen vary with constitution of diet; among the metabolites produced, volatile fatty acid content and proportion of propionate is related positively with milk yield, whereas milk fat content is related positively with concentration of ruminal acetate and butyrate. Thus, postulated (A+B)/P ratio is better indicative of milk fat than A/P ratio. Within normal limits of dietary protein, to a major extent, VFA content in rumen is affected by the proportion and source of roughage, kind of grain supplement, level and source of sugar and starch in the ration. With moderate levels of concentrate, maize sustains higher milk yields, however, higher milk fat content can be achieved with barley as grain supplement. Good quality alfalfa hay sustain more milk than other dry roughages, whereas straws can be used up to 30 percent in rations of lactating cow. Thus, there is scope to increase milk fat content and milk production as well by altering production of volatile fatty acids through judicious manipulation of diet.

REFERENCES

Abou-Akkada, A. R. and K. El-Shazly 1958. Studies on the nutritive value of some common Egyptian feeding stuffs. 2. Effects of concentrates rich in protein on cellulose and dry matter digestion. J. Agric. Sci. (Camb.) 51:157-163.

Akkan, S. and K. ozkan. 1987. Effect of roughage: concentrate ratio on yield and composition of milk and rumen contents. Ege-Universitesi-Ziraat-Fakultesi Dergisi 24(1):261-273.

Altman, J. F. B. 1980. In Feeding Strategies for Dairy Cows. Eds. Broster, W. H., C. L. Johnson and Taylor, J. C. Agricultural Research Council. London p. 151.

Amir, S. 1974. Paper to Stockman's School, San Antonio, Texas, January 1974. Cited in Recent Advances in Animal Nutrition-1978. Eds. Haresign, W. and Lewis, D. Butterworths, London p. 120.

Anderson, M. J., D. C. Adams, R. C. Lamb and J. L. Walters. 1979. Feeding whole cottonseed to lactating cows. J. Dairy Sci. 62 : 1098-1103.

Anis, S. M. K., M. M. El-abd, K. A. Khafagi and A. M. Abou. 1991. Supplementation of field by-products by El-mufeed in relation to milk production and composition. Egyptian J. Dairy Sci. 19 : 145-155.

Balch, C. C. 1971. Proposal to use time spent chewing as an index of the extent to which diets for ruminants possess the physical property of fibrousness characteristic of roughage. Br. J. Nutr. 26 : 383-392.

Balch, C. C. 1972. In Handbuch der Tierernahrung. Eds. W. Lenkit, K. Breirem, and E. Crasemann Paul Parey Hamburg 2, p. 259.

Balch, C. C., D. A. Balch, S. Bartlett, Z. D. Hosking, V. W. Johnson, S. J. Rowland and J. Turner. 1955. Studies of the secretion of milk of low fat content by cows on diet low in hay and high in concentrates. V. The importance of the type of starch in the concentrates. J. Dairy Res. 22 : 10-15

Banks, W., J. L. Clapperton and M. E. Kelly. 1980. Effect of oil enriched diets on the milk yield and composition and physical properties of milk fat of dairy cows receiving a basal ration of grass silage. J. Dairy Res. 47 : 277-286.

Banks, W., J. L. Clappetson and W. Steele. 1983. Dietary manipulation of the content and fatty acid composition of milk fat. Proc. Nutr. Soc. 42(3) : 399-406.

Bauman, D. E., C. L. Davis and H. F. Bucholtz. 1971. Propionate production in rumen of cows fed either a control or high grain low fibre diet. J. Dairy Sci. 54 : 1282-1287.

Beauchemin, K. A. 1991. Effects of dietary neutral detergent fibre concentration and alfalfa hay quality on chewing, rumen function and milk production of dairy cow. J. Dairy Sci. 74 : 3140-3151.

Beever, D. E. and D. J. Thomson. 1981. In Recent Developments in Ruminant Nutrition. Haresign, W. and D. J. A. Cole (Eds.), Butterworths London p. 82.

Beever, D. E. and B. R. Cottrill. 1993. Protein system for ruminant livestock : A European Assessment. J. Dairy Sci. 77 : 2031-2043.

Belibasakis, N. G. and D. Tsirgogianni. 1995. Effects of whole cottonseeds on milk yield, milk composition and blood components of dairy cows in hot weather. Anim. Feed. Sci. Technol. 52 : 227-235.

Bhoot, S. R. 1989. Nutrient availability and utilization in ruminants fed proteins with different protective agents. Ph. D. Thesis, NDRI, Karnal.

Bines, J. A. 1979. In Feeding Stragegy for high yielding dairy cow. Eds. Brooster, W. H. and H. Swan Granada Publishing, St. Albans, p. 23.

Blair, T., D. A. Christensen and J. G. Mann. 1974. Performance of lactating dairy cows fed complete pelleted diets based on wheat straw. Can. J. Anim. Sci. 54 : 347-354.

Blaxter, K. L. 1967. The energy metabolism of Ruminants. Hiutchinson & Co. London.

Broster, W. H. and C. Thomas. 1981. The influence of level and pattern of concentrate input on milk output. In Recent Advances in Animal Nutrition. Ed. Haresign, W. Butterworths London. pp. 49-69.

Broster, W. H., J. D. Sutton, J. A. Bines, T. Smith, J. W. Siviter and V. J. Broster. 1977. Proc. Nutr. Soc. 36 : 145A.

Broster, W. H., J. D. Sutton and J. A. Bines. 1979. Concentrate forage ratios for high yielding dairy cows. In Recent Advances in Animal Nutrition. Eds. Haresign and D. Lewis Butterworths, London. pp. 99-126

Broster, W. H., J. D. Sutton and J. A. Bines. 1981. Forage ratio for high yielding dairy cows. In Recent Developments in Ruminant Nutrition. Haresign, W. and D. J. A. Cole (Eds.), Butterworths London. p. 337.

Broster, W. H., J. D. Sutton, J. A. Bines, V. J. Broster, T. Smith, J. W. Siviter, V. W. Johnson, D. J. Napper and E. Schuller. 1985. The influence of plane of nutrition and diet composition on the performance of dairy cows. J. Agric. Sci. (Camb.) 104 : 535-557.

Brown, C. A., P. T. Chandler and J. B. Holter. 1977. Development of predictive equations for milk yield and dry matter intake in lactating cows. J. Dairy Sci. 60 : 1739-1754.

Chamberlain, D. G., P. C. Thomas, W. A. Wilson, M. M. Kassam and S. C. Robertson. 1984. The influence of type of carbohydrate in the supplementary concentrate on the utilization of silage diets for milk production. Proc. VII Silage Conference. Eds. Gordon, F. J. and E. F. Unsworth Queens University, Belfast. pp. 37-38.

Chander, H. and R. S. Ludri. 1979. Influence of wheat straw as roughage source of fibre on composition of rumen volatile fatty acids and milk fat. Indian J. Dairy Sci. 32(2) : 203-205.

Chaturvedi, O. H. 1992. Effect of dietary RDP/UDP ratio on the flow of microbial and dietary NAN at abomasum and efficiency of nutrient utilization for milk production in crossbred cattle. Ph. D. Thesis, NDRI, Karnal.

Chauhan, T. R., R. S. Sangwan, S. S. Dahiya and B. S. Punia. 1994. Effect of roughage to concentrate ratio on rumen fermentation, nutrient utilization and some blood constituents in growing buffalo calves. Indian J. Anim. Sci. 64(3) : 307-311.

Clark, J. M. 1975. Lactational responses to post-ruminal administration of proteins and amino acids. J. Dairy Sci. 58 : 1178-1197.

Clark, J. H. and C. L. Davis. 1980. Some aspects of feeding high producing dairy cows. J. Dairy Sci. 63 : 873-891.

Clark, J. M., H. R. Spires and R. G. Derrig. 1973. Post-ruminal administration of glucose and sodium caseinate in lactating cows. J. Anim. Sci. 37 : 441 (Abstr.).

Christensen, R. A., G. L. Lynch and J. H. Clark. 1993. Influence of amount and degradability of protein and production of milk and milk components by lactating Holstein cows. J. Dairy. Sci. 76 : 3490-3496.

Coppock, C. E. and D. L. Wilks. 1991. Supplemental fat in high energy rations for lactating cows : Effect on intake, digestion, milk yield and composition. J. Anim. Sci. 69(9) : 3826-3837.

Coppock, C. E., J. K. Lauham and J. L. Horner. 1987. A review of nutritive value and utilization of whole cottonseed, cottonseed meal and associated by-products by dairy cattle. Anim. Feed. Sci. Technol. 18 : 89-129.

Cressmann, S. G., D. G. Grieve, G. K. Macleod and L. G. Young. 1977. Influence of dietary protein concentration on milk production by dairy cattle during early lactation. J. Dairy Sci. 60(Suppl. 1) : 68 (Abstr.).

Davis, C. L. and R. E. Brown. 1970. Metabolic disorders of the ruminant. Low milk fat syndrome. In Physiology of digestion and metabolism in the ruminant. Ed. Phillipson, A. T. Oriel Press Ltd., England. pp. 545.

Derrig, R. G., J. H. Clark and C. L. Davis. 1974. Effect of abomasal infusion of sodium caseinate on milk yield, Nutilization and amino acid nutrition of the dairy cow. J. Nutr. 104 : 151-159.

De Peters, E. J. and E. M. Kesler. 1980. Partial replacement of concentrate by high quality hay for cows in early lactation. J. Dairy Sci. 63 : 936-944.

De Peters, E. J. and S. J. Tayler. 1985. Effect of feeding corn or barley on composition of milk and diet digestibility. J. Dairy Sci. 68 : 2027-2032.

De Peters, E. J., S. J. Tayler, A. A. Franke and A. Aguirre. 1985. Effects of feeding whole cottonseed on composition of milk. J. Dairy Sci. 68 : 897-902.

De Visser, H. and A. M. De Groot. 1980. The influence of sugar and starch content of concentrate on feed intake, rumen fermentation, production and composition of milk. In Proc. TV Internat. Conf. Production Disease in Farm Animals. Eds. D. Gieseeke, G. Dirksen and M. Stangassinger Tierarztliche Fakultat der Universitat, Munich. pp. 41-48.

Dutta, T, K, and S. S. Thakur. 1992. Effect of feeding barley, maize or oat grain in concentrate mixture on rumen fermentation pattem and nutrient utilization in crossbred cattle. Indian J. Anim. Sci. 62(12) : 1203-1208.

Ekern, A. 1970. In Dairy Nutrition, C. Campbell (Ed.). U. S. Feed Grain Council, Mitcham, U. K. Vale Press. p. 63.

El-Gallard, T. T., E. A. Gihad, S. M. Allam and T. M. El-Bedawy. 1988. Effect of energy intake and roughage ratio on the lactation of Egyptian Nubian (Zaraibi) goats. Small Ruminant Res. 1(4) : 327-341.

Elliot, J. M. and J. K. Loosli. 1959a. Effect of dietary ratio of hay to concentrate on milk production, ration digestibility and urinary energy losses. J. Dairy Sci. 42 : 836-842.

Elliot, J. M. and J. K. Loosli. 1959b. Relationship of milk production efficiency to its relative proportion of its rumen volatile fatty acids. J. Dairy Sci. 42 : 843-848.

Erfle, J. D., S. Mahadevan, R. M. Teather and F. D. Saur. 1983. The performance of lactating cows fed urea treated com silage in combination with soyabean or fish meal containing concentrates. Can. J. Anim. Sci. 63 : 191-199.

Flatt, W. P., P. W. Moe, N. W. Hooven, R. P. Lehmann, E. R. Orskov and R. W. Hamkin 1969. In Energy Metabolism of Farm Animals. Eds. Blaxter, K. L., G. Thorbek and J. Kielanowski Oriel Press, New Castle upon Tyne. pp. 221.

Garg, M. R. 1989. Effect of supplementary straw based diet with urea molasses mineral block lick on rumen fermentation pattem, nutrient utilization and growth in crossbred cattle. Ph. D. Thesis, Kurukshetra University, Kurukshetra.

Goetch, A. L. and M. L. Galyean. 1982. Effect of dietary concentrate level on rumen fluid dilution rate. Can. J. Anim. Sci. 62 : 649-652.

Gordon, F. J. and T. J. Forbes. 1971. Effect of fibre level in diet of dairy cows on milk yield and composition. J. Dairy Res. 38 : 381-391.

Grieve, D. G., G. K. Mc Leod and J. B. Stone. 1974. Effect of diet protein percent for lactating dairy cows. J. Dairy Sci. 57: 633 (Abstr.).

Grings, E. F., R. E. Roffler and D. P. Dietelhoff. 1991. Response of dairy cows in early lactation to addition of cottonseed meal in alfalfa hay based diets. J. Dairy Sci. 74 : 2580-2587.

Halevi, A., H. Neumark and S. Amir. 1973. Straw in diffeent proportions as sole roughage in diets for cows in mid lactation. J. Dairy Sci. 56(11) : 1424-1428.

Hodgson, J. C. and P. C. Thomas. 1975. A relationship between molar proportion of propionic acid and the clearance rate of liquid phase in the rumen of sheep. Brit. J. Nutr. 33 : 447-456.

Holmes, C. W., G. F. Wilson, D. D. S. Mackenzie, D. S. Flux, I. M. Brookes and A. W. E. Davey. 1987. In Milk Production from Pasture. Butterworths, New Zealand. pp. 188-189.

Horner, J. L., L. M. Windle, C. E. Coppock, J. M. Labore, J. K. Lanham and D. H. Nave. 1988. Effects of whole cottonseed, naicin and niacinamide on the *in vitro* rumen fermentation on the lactating cows. J. Dairy Sci. 71(12) : 3334-3344.

Hovell, F. D. Deb and J. F. D. Greenhalgh. 1972. Utilization of salts of acetic, propionic and butyric acids by growing lambs. Proc. Nutr. Soc. 31 : 68A.

Huhtanen, P., S. Jaakkola and E. Jaarisalo. 1995 : The effects of concentrate energy source on milk production of dairy cows given grass silage based diets. Anim. Sci. 60 : 31-40.

Jelec, S. 1990. Nutritional factors and milk composition with special reference to milk fat. Stocerstvo 44(5-6) : 199-208.

Jorgensen, N. A., L. H. Schultz and G. R. Barr. 1965. Factors influencing milk fat depression on rations high in concentrates. J. Dairy Sci. 48 : 1031-1039.

Journet, M. and Y. Chiliard. 1985. Influence d i' alimentation sur la composition du lait. 1. Taux butyreaux, facteurs generaux. Bull. Tech. CRZV Theix. Inst. Natl. Rech. Agron. 60 : 13-16.

Kakkar, V. K. and V. D. Mudgal. 1979a. Cottonseed vs. urea molasses complex feeding. I . Effect on the digestibility of nutrients and efficiency of nitrogen utilization in lactating Sahiwal cows. Indian J. Anim. Sci. 49(3) : 165-169.

Kakkar, V. K. and V. D. Mudgal. 1979b. Cottonseed vs. cottonseed cake feeding. IV. Effects on milk production, feed conversion efficiency and cost of milk production in lactating Sahiwal cows (Bos indicus). Indian J. Dairy Sci. 32(1) : 47-52.

Kakkar, V. K. and V. D. Mudgal. 1981. Cottonseed cake vs. urea molasses complex feeding. 2. Effect on milk production, feed conversion efficiency and cost of milk production in Sahiwal cows. Indian J. Anim. Sci. 51(5) : 508-513.

Kapoor, V. 1989. Effect of dietary flouride on phosphorus utilization, thyroid function, rumen metabolism and milk constituents of ruminants. Ph. D. Thesis, Kurukshetra University, Kurukshetra.

Kay, M. 1972. Cereal Processing and Digestion. US Feed Grain Council. pp. 39-52.

Kumar, V. 1989. Growth rate nutrient utilization and abomasal N flow studies in crossbred calves fed ammoniated wheat straw supplemented with by-pass proteins. Ph. D. Thesis, Kurukshetra University, Kurukshetra.

Kung, L. Jr., R. S. Tung and B. R. Carmean. 1992. Rumen fermentation and nutrient digestion in cattle fed diets varying in forage and energy source. Anim. Feed Sci. Technol. 39 : 1 -12.

Kurar, C. K., Madhu Mohini, A. Mehta and Mangat Ram. 1996. Comparative feed conversion efficiency for growth and milk production in cattle and buffaloes using feed containing bypass protein. Final Report, Technol. Mission Project, NDRI, Karnal, India.

Laird, R., J. D. Leever, P. R. Moisey and M. E. Castle. 1981. The effect of concentrate supplements on the performance of dairy cows offered grass silage *ad libitum*. Anim. Prod. 33 : 199-209.

Lees, J. A., J. D. Oldham, W. Haresign and P. C. Garnsworthy. 1990. The effect of patterns of rumen fermentation on response by dairy cows to dietary protein concentration. Brit. J. Nutr. 63 : 177-186.

Leng, R. A. and T. R. Preston. 1976. Sugarcane for cattle production : present constraints, perspectives and research priorities. Trop. Anim. Prod. 1 : 1-22.

Ludri, R. S. 1978. Effect of added acetate and straw to the daily ration on the yield and composition of milk, nutrient utilization and energetic efficiencies in crossbred cows. Indian J. Anim. Sci. 48(5) : 362-365.

Ludri, R. S. 1979. Influence of added fibre to the daily ration on the quality and quantity of milk, nutrient utilization and energetic efficiencies in crossbred cows. Indian J. Anim. Sci. 49(1) : 22-24.

Mahal, G. S., S. S. Randhawa and B. Singh. 1997. Effect of feeding different roughage to concentrate ratios on nutrient utilization and productive performance of crossbred cows. Indian. J. Anim. Prod. Mgmt. 13 : 93-97.

Mangat Ram, A. K. Tripathi and P. J. George Kunju. 1985. Effect of different levels of concentrate in the ration on ruminal fermentation pattern, rumen volume and flow rate of digesta. Indian J. Anim. Nutr. 2(4) : 189-193.

Martin, P. A. 1986. The effects of polyols and selected starch sources on metabolism and milk production of dairy cows. Ph. D. Thesis, University of Glassgow. U. K.

Martin, P. A. and P. C. Thomas. 1988. Dietary manipulation of the yield and composition of milk. 1. Effects of dietary inclusion of barley and oats in untreated and formaldehyde treated forms on milk fatty acid composition. J. Sci. Food Agric. 43 : 145-152.

Mc Carthy, R. D. Jr., T. H. Klusmeyer, J. H. Clark and D. R. Nelson. 1987. Effects of source of protein and carbohydrate on ruminal fermentation and flow of nutrients to the small intestine of lactating cows. J. Dairy Sci. 70. (Suppl. 1) : 114 (Abstr.).

Moe, P. W. and H. F. Tyrrell. 1975. Efficiency of conversion of digested energy into milk. J. Dairy Sci. 58 : 602-610.

Mohamed, O. E., L. D. Satter, R. R. Grummer and F. R. Ehle. 1988. Influence of dietary cottonseed and soyabean on milk production and composition. J. Dairy Sci. 71 : 2677-2688.

Moody, E. G. and A. P. Cook. 1961. Whole cottonseed in limited fibre rations for dairy cattle. J. Dairy Sci. 44 : 1176 (Abstr.).

Moody, E. G. and W. J. Barnes. 1966. cottonseed and oil in dairy rations at two roughage levels. J. Dairy Sci. 49 : 719 (Abstr.).

Moran, J. B. 1986. Cereal grain in complete diets for dairy cow : a comparison of rolled barley, wheat and oats and of three methods of processing oats. Anim. Prod. 43 : 27-36.

Morely, G. M. L. 1970. Studies on the effect of different feeds on quality and quantity of milk in dairy cattle. Ph. D. Thesis, Punjab University, Chandigarh.

Mudgal, V. D. and J. P. Puri. 1977. Effect of feeding free and molasses bound urea on rumen metabolism in cattle. Indian J. Dairy Sci. 30(4) : 264-269.

Norfeldt, S., I. Iwanaga, K. Mortia, L. A. Henke and K. S. Tom Annie. 1950. Influence of crude fibre in the ration on efficiency of feed utilization by dairy cows. J. Dairy Sci. 33 (7):473-485.

NRC 1989. National Research Council. Nutrient Requirements of Dairy Cattle. VI Edn. National Academy of Science, Washington, D. C.

Ohajuruka, O. A. and D. C. Palmquist. 1989. Responses of high producing dairy cows to high levels of dried corn gluten feed. Anim. Feed Sci. Technol. 24 : 191-200.

Oldenbrock, J. K. 1979. Differences in intake of roughage between cows of three breeds fed two levels of concentrate according to milk yield. Livestock Prod. Sci. 6 : 147-151.

Oldham, J. D. 1984. Protein energy interrelationship in dairy cows. J. Dairy Sci. 67 : 1090-1114.

Orskov, E. R. and G. W. Reid. 1985. Use of by-products and supplementary protein in dairy cow nutrition. Vet. Rec. 116 : 607-610

Orskov, E. R., D. A. Grubb and R. N. B. Kay. 1977. Effect of post-ruminal glucose or protein supplementation on milk yield and composition in Friesian cows in early lactation and negative energy balance. Brit. J. Nutr. 38 : 397-405.

Orskov, E. R., M. Huges-Jones and I. McDonald. 1981a. In Recent Developments in Ruminant Nutrition. Haresign, W. and D. J. A. Cole (Eds.), Butterworths London. p. 17.

Orskov, E. R., M. Hughes-Jones and I. McDonald. 1981. Degradability of protein supplements and utilization of undegraded protein by high producing dairy cows. In : Recent Development in Ruminant Nutrition. W. H. Haresign and D. J. A. Cole (Eds.), Butterworths London. pp. 25-28.

Owen, J. B. 1975. In Simplified Feeding for milk and Beef. C. Campbell (Ed.). U. S. Feed Grains Council, Leatherherd, U. K., Reproprint. p. 85.

Owen, J. B. 1976. Complete diets for dairy cattle. World Rev. 20:36-41.

Pachauri, V. C. and S. S. Negi. 1978. A note on the effect of replacing groundnut cake by soyabean as protein supplement in ration of Jersey crossbred milk cows. Indian J. Anim. Sci. 48(8) : 615-617.

Palmquist, D. L. and T. C. Jenkins. 1980. Fat in lactation rations : Review. J. Dairy Sci. 63 : 1-14.

Patel, J. S. and V. V. Sharma. 1983. Effect of feeding wheat straw and concentrate in varying ratios on the efficiency of nutrient utilization in lactating crossbred cows. Indian J. Anim. Sci. 53(11) : 1186-1190.

Patle, B. R. 1973. Studies on the effect of plane of nutrition on utilization of feed nutrients for milk production in crossbred cows. Ph. D. Thesis, Panjab University, Chandigarh.

Perry, F. G. and G. K. Mc Leod. 1968. Effects of feeding raw soyabeans on rumen metabolism and milk composition of dairy cows. J. Dairy Sci. 51 : 1233-1238.

Petit, H. V. and G. F. Tremblay. 1995. Milk production and intake of lactating cows fed grass silage with protein and energy supplements. J. Dairy Sci. 78(2):353-361.

Phipps, R. H., I. A. Bines, R. F. Weller and J. Thomas. 1984. Complete diets for dairy cows: comparison between complete diets and separate ingredients. J. Agric. Sci. (Camb.) 103:171-180.

Punia, B. S. and D. D. Sharma. 1985. Effect of dietary energy source on volatile fatty acid and pH values *in vitro*. Indian J. Anim. Nutr. 2(4):183-186.

Puri, J. P. 1988. Effect of ammonia treatment of low and high lignified cellulosic feeds on chemical composition, fibre degradability, growth and nutrient utilization in cattle. Ph. D. Thesis, Kurukshetra University, Kurukshetra.

Roffler, R. E., L. D. Satter, A. R. Hardie and W. J. Tyler. 1978. Influence of dietary protein concentration on milk production by dairy cattle during early lactation. J. Dairy Sci. 61:1422-1428.

Roffler, R. E., J. E. Wray and L. D. Satter. 1986. Production responses in early lactation to addition of soyabean meal to diets containing predominatly corn silage. J. Dairy Sci. 69: 1055-1062.

Ronning, M. and R. C. Laben. 1966. Response of lactating cows to free choice feeding of milled diets containing 10 to 100% concentrates. J. Dairy Sci. 49:1080-1085.

Rook, J. A. F. 1961. Variation in the chemical composition of the milk of the cow. part I. Dairy Sci. Abstr. 23:251-258.

Rook, J. A. F. and C. C. Balch. 1961. The effects of intraruminal infusions of acetic, propionic and butyric acids on the yield and composition of the milk of the cow. Brit. J. Nutr. 15:361-369.

Rook, J. A. F. and C. C. Balch and V. W. Johnson. 1965. Further observations on the effects of intra-ruminal infusion of volatile fatty acids and lactic acid on the yield and composition of the milk of the cows. Brit. J. Nutr. 19:93-99.

Sangwan, D. C., K. Pradhan and V. Sagar. 1987. Effect of dietary fibre on rumen metabolites and nutrient digestibility in cattle and buffalo. Indian J. Anim. Sci. 57(6):562-569.

Sangwan, D. C., K. Pradhan, D. R. Bhatia, V. Sagar and S. Singh. 1990. Associative effect of wheat straw and oat hay with protein supplements on rumen metabolites and nutrient digestibility in cattle and buffalo. Indian J. Anim. Sci. 60(4): 472-479.

Sawal, R. K. and G. P. Singh. 1986. Effect of intra-ruminal infusion of salt on rumen fluid flow rate and volatile fatty acid production rate in adult cattle. J. Nuclear Agric. Biol. 15(2):94-100.

Sharma, D. D. and V. D. Mudgal. 1975. Metabolic changes in the rumen of cows and buffaloes kept on restricted and ad lib berseem feeding. Indian J. Anim. Sci. 45(4):189-192.

Singh, N., T. K. Walli and V. D. Mudgal. 1985. Level of green fodder in the ration of buffaloes for optimum milk production. Indian J. Dairy Sci. 40(2):195-199.

Sivaiah, K. and V. D. Mudgal. 1983. Effect of feeding different levels of protein and energy on feed utilization and milk production in buffaloes. Indian J. Dairy Sci. 36(1):85-92.

Smith, N. E., L. S. Collar, D. L. Bath, W. L. Dunkley and A. A. Franke. 1981. Digestibility and effects of whole cottonseed fed to lactating cows. J. Dairy Sci. 64:2209-2215.

Soni, V. K. and D. D. Sharma. 1982. Influence of concentrate level on nitrogen metabolites and volatile fatty acid pattern in goat rumen. Indian J. Dairy Sci. 35:460-466.

Sood, R. 1982. *In vivo* rumen metabolism studies in buffaloes given decorticated expeller crushed vs. solvent extracted cottonseed cake. M. Sc. Thesis, Kurukshetra University, Kurukshetra.

Srivastava, A. and V. Mani. 1991. Rumen fermentation pattern of soyabean protein in diet as affected by level of fat and treatment with formaldehyde. Indian J. Anim Sci. 61(6): 655-657.

Stanley, R. W., E. Cobb, K. Mortia, J. Carpenter and Ishizaki. 1969. The effect of feeding whole cottonseed to lactating dairy cattle on milk and milk fat production. Hawaii Agric. Exp. Sta. Res. Rep. p. 177.

Staples, C. R., C. L. Davis, G. C. Mc Coy and J. H. Clark. 1984. Feeding value of wet corn gluten feed for lactating dairy cow. J. Dairy Sci. 67:1217-1220.

Steele, W., R. C. Noble and J. H. Moore. 1971. The effects of 2 methods of incorporating soyabean oil into the diet on milk yield and composition in the cow. J. Dairy Res. 38:43-48.

Storry, J. E. 1981. The effect of dietary fat on milk composition. In Recent Advances in Animal Nutrition. Ed. Haresign, W. Butterworths, London. pp. 1-33.

Storry, J. E., B. Tuckley and A. J. Hall. 1969a. The effects of intravenous infusions of triglycerides on the secretion of milk fat in the cow. Brit. J. Nutr. 23:157-171.

Storry, J. E., A. J. Hall, B. Tuckley and D. Millard. 1969b. The effects of intravenous infusions of cod liver and soyabean oils on secretion of milk fat in the cow. Brit. J. Nutr. 23: 173-180.

Sutton, J. D. 1976. In Principles of Cattle Production. Swan, H. and W. H. Broster (Eds.), Butterworths London. p. 121.

Sutton, J. D. 1980. Influence of nutritional factors in the yield and content of milk fat: dietary components other than fat. Bull. Int. Dairy Fed. 125:126-134.

Sutton, J. D. 1981. Concentrate feeding and milk composition. In Recent Advances in Animal Nutrition. Ed. Haresign, W. Butterworths, London. pp. 35-48.

Sutton, J. D. 1984. Feeding and milk fat production. In Milk Compositional Quality and its Importance in Future Markets. Eds. Castle, M. E. and Gunn, R. G. Brit. Soc. Anim. Prod. Occasional Publication No. 9, Edinburg: BSAP. pp. 43-52.

Sutton, J. D. 1985. The digestion and absorption of energy substrates in lactating cow. J. Dairy Sci. 68:3376-3393.

Sutton, J. D. 1989. Altering milk composition by feeding. J. Dairy Sci. 72:2801-2814.

Sutton, J. D., J. D. Oldham and I. C. Hart. 1980. Products of digestion, hormones and energy utilization in milk cows given concentrates containing varying proportions of barley and maize. In Energy Metabolism. Ed. Mont, L. E. Butterworths, London. pp. 303-306.

Sutton, J. D., J. A. Bines and D. S. Napper. 1985a. Composition of starchy and fibrous concentrates for lactating dairy cows. Anim. Prod. 40:533. (Abstr.).

Sutton, J. D., W. H. Broster, D. J. Napper and J. W. Sivitger. 1985b. Feeding frequency for lactating cows; effects on digestion, milk production and energy utilization. Br. J. Nutr. 53:117-130.

Sutton, J. D., J. A. Bines, S. V. Morant, D. J. Napper and D. I.

Givens. 1987. A comparison of starchy and fibrous concentrates for milk production and energy utilization and hay intake by Friesian cows. J. Agric. Sci. (Camb.) 109:375-386.

Thomas, P. C. and D. G. Chamberlain. 1984. Manipulation of milk composition to meet market needs. In Recent Advances in Animal Nutrition. Eds. Haresign, W. and D. J. A. Cole Butterworths, London. pp. 219-245.

Thomas, P. C. and P. A. Martin. 1988. The influence of nutrient balance on milk yield and composition. In: Nutrition and Lactation in the Dairy Cow. P. C. Garnsworthy (Ed.), Butterworths London England.

Thomas, C., K. Aston, J. Bass, S. R. Daley and P. M. Hughes. 1984. The effect of composition of concentrate on the voluntary intake of silage and milk output. Anim. Prod. 38: 519 (Abstr.).

Tiwari, D. P. and I. S. Yadava. 1989. Effect of feeding formaldehyde treated mustard cake on rumen metabolites and transaminase activity in buffaloes. Indian J. Anim. Sci. 59 (12): 1539-1547.

Tyrrell, H. F. 1980. Limits to milk production efficiency by dairy cows. J. Anim. Sci. 51: 1441-1447.

Van Es, A. J. H., H. J. Nijkamp and J. E. Vogt. 1970. Food evaluation for dairy cows. Proc. V Symp. Energy Metabolism. Vitznau, Switzerland. E. A. A. P. Publ. 13, 61.

Van Horn, H. H., C. A. Zometa, C. J. Wilcox, S. P. Marshall and B. Harris Jr. 1979. Complete rations for dairy cattle. Ⅷ. Effect of percent and source of protein on milk yield and ration digestibility. J. Dairy Sci. 62: 1086-1093.

Van Soest, P. J. and N. N. Allen. 1959. Studies on relationships between rumen acids and fat metabolism of ruminants fed restricted roughage diets. J. Dairy Sci. 42(12): 1977-1985.

Verite, R. and M. Journet. 1977. Utilization des fourteaux traites au formol par les vaches laitieres. Ⅱ. Effects sur la production laitieres. du treatment des fourteaux et du viveau d' apport azote an debut de la lactation. Ann. Zootech. 26:188-205.

Verma, D. N., A. Verma, U. B. Singh, S. K. Ranjhan and S. B. Johri. 1975. Digestibility of nutrients and VFA production rates in buffalo calves fed on rations of diffeent crude protein content. Indian J. Anim. Sci. 45(6): 321-325.

Wagsness, P. J. and L. D. Muller. 1981. Maximum forages for dairy cow: Review J. Dairy Sci. 64: 1-13.

Waldern, D. E. 1973. Rapeseed meal vs. soyabean meal as the only protein supplement for lactating cows fed corn silage roughage rations. Can. J. Anim. Sci. 53: 107-112.

Wattiaux, M. A., D. K. Combs and R. D. Shaver. 1994. Lactational responses to ruminally undegradable protein by dairy cows fed diets based on alfalfa silage. J. Dairy Sci. 77: 1604-1617.

White, B. G., J. R. Ingalls and H. R. Sharma. 1987. The addition of whole sunflower seeds and sodium bicarbonate to fat depressing diets for lactating cows. Can. J. Anim. Sci. 63:437-445.

Yadav, P. and S. K. Bhatia. 1992. Rumen metabolism in buffalo fed straws supplemented with different oil cakes. Indian J. Anim. Nutr. 9(1): 63-66.