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Influence of Dietary Energy and Protein Intake on Yield and Composition of Milk in Crossbred Dairy Cows

Research Article

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ABSTRACT

The study was carried out on 120 crossbred Holstein × Shahiwal dairy cows for a period of 150 days to quantify the influence of dietary energy and protein intake on yield and composition of milk. Total 12 dairy farms having similar housing systems and holding at least 20 dairy cows in between mid to late lactation were selected for study purposes. The farms were located in the peri-urban and urban areas of Chittagong, Bangladesh. Milk samples were collected from individual cow. Milk from cows having same body condition scoring (BCS) were mixed together to make a composite sample. Chemical analyses of the samples were carried out in triplicate for fat, protein, lactose, total solids (TS), solids not fat (SNF) and ash. Dietary metabolizable energy (ME) and crude protein (CP) intake were measured by analyzing the amount of total mixed ration ingested by the individual cow. Results indicated that, ME intake (MJ/d) significantly ($P<0.01$) influenced milk yield, milk fat and TS content of milk in crossbred Holstein Friesian dairy cows. Similar to ME, CP intake (g/d) also influenced ($P<0.01$) milk yield, fat, protein, lactose, TS and ash content of milk. Correlation coefficient matrix indicated that, milk yield was positively correlated with ME and CP intake. However, there was a negative association between ME or CP intake and milk protein, lactose, TS and SNF of milk even though the strength of association was variable. It could therefore be inferred that, adequate dietary ME and CP intake is important to optimize milk yield and milk composition in crossbred Holstein × Shahiwal dairy cows reared under intensive farming systems in tropical regions.

KEY WORDS crossbred dairy cow, metabolizable energy, milk composition, milk yield.

INTRODUCTION

There are a number of fundamental factors that affects milk components such as genetics, breed, environment, parity, stage of lactation, disease, season and age of the cow. Of all the factors, nutrition offers the most effective means of rapidly altering milk composition. Although, almost all components of milk are subjected to manipulation, the extents are variable. In general, fat percent and the fatty acid profile of milk are most likely to change, whereas lactose is least sensible and protein is intermediate. Again, changes in milk composition are not always obvious. For example, total protein concentration could remain constant, but significant changes could occur in the ratio of casein to non-protein nitrogen. Additionally, the dairy cow is a relatively inefficient converter of dietary nitrogen into milk protein. Therefore, attempts to increase milk protein content through protein or amino acid supplementation often result smaller than anticipated response (Bequette *et al.* 1998). This lack of knowledge about how dietary protein and amino acids influence the composition and yield of milk protein makes it difficult to formulate diets that are biologically efficient and economical.

Similar to protein, substantial changes may occur in the fatty acid composition of milk without marked changes in fat percent. Milk fat is a complex lipid containing more than 400 distinct fatty acids. Some important features of bovine milk fat are the presence of short chain, odd and branched chain fatty acids, a high proportion of saturated fatty acids, a low proportion of polyunsaturated fatty acids and a relatively high proportion of trans-fatty acids, including conjugated linoleic acid. Milk fat is synthesized in the mammary gland through esterification of free fatty acids to glycerol, resulting in triacylglycerols, which make up 97-98% of the milk lipid. The fatty acids are either synthesized in the mammary gland from precursors, or they enter the gland as preformed fatty acids, which come either from the diet or from mobilization of body fat stores. Interestingly, all these processes of milk fat synthesis are subjected to dietary change.

Finally, whatever may be the extent, the great diversity of possible approaches to alter milk composition is basically a consequence of the complexity of multiple physiological and environmental processes that may mask even the effect of nutrition on milk composition. Most of the previous studies were carried out mostly in pasture based feeding systems to quantify the influence of nutrition on milk composition in high yielding Holstein- Friesian dairy cows reared mostly under pasture based feeding systems in temperate regions.

Friesian X Shahiwals are well adapted in Bangladesh because although purebred Friesian cows produce maximum milk, they cannot survive in tropical countries due to high temperature and humidity. Therefore, the current study aims to find out the association among dietary energy and protein intake and their subsequent effect on milk composition in medium yielding crossbred Friesian × Shahiwal dairy cows reared under intensive farming conditions in the tropical region.

MATERIALS AND METHODS

The study was carried out in 12 different commercial dairy farms located in the peri-urban and urban areas of Chittagong, Bangladesh. The study area has a latitude of 22 ˚21'N, longitude 91 ˚49'E and elevation 29 m. The area is fairly hot with annual average temperature of 25.1 ˚C. The variation of daily average temperature is 8.8 ˚C. The mean monthly temperature has a variation of 9 ˚C, the hottest month is May is having a mean temperature of 28 ˚C. The coolest month is January which has a mean temperature of 19 ˚C. The average annual relative humidity of the area is 73.7% and average monthly relative humidity ranges from 58% in January to 86% in August. The area has an average of 2735 mm rainfall per year. There are 135 days per year with more than 0.1 mm of rainfall. The driest weather is in January when an average of 6 mm of rainfall. The wettest weather is in July when there occurs an average of 598 mm of rainfall. The longest day of the year is 13:22 hours long and the shortest day is 10:37 hours long. The current study was carried out during April to August, 2013.

In the study area, farms holding at least 20 Friesian × Shahiwal crossbred lactating dairy cows were selected for study purposes. The selected farms were Azizia dairy farm, Bhuyian dairy farm, Janata dairy farm, Jane Alam dairy farm, Jarif dairy farm, Liza dairy farm, Belal dairy farm, Mollah dairy farm, Rajabadsha dairy farm, Samia dairy farm, Bandhan dairy farm and Mainuddin dairy farm. Cows were reared in permanent confinement using double row face out system stanchion barn house. The floors of the houses were cemented type with the open air ventilation system.

Feeding systems used were total mixed ration (TMR) type provided in confinement feeding. Farmers provided fresh chopped roadside grass, german grass (*Echinochloa polystachya*), helencha (*Enhydra fluctuans*) and water hyacinth (*Eichhorna cramipes*) in addition to dry rice straw. During the rainy season they cultivated plenty of german grasses, however, in the dry season they provided only roadside grass, helencha and water hyacinth as green roughage. Along with green forages, they provided concentrate mixture consists of broken maize, broken rice, rice polish, wheat bran, mustard oil cake, til oil cake, common salt and vitamin mineral premix. Farmers, rarely supplied urea treated straw in few farms. Herd size ranged from 50 to 100. The average herd size of the selected farms was 75 cows. The average milk production per herd per year based on the 12 months just finished. Those farms who frequently (several times in a particular year) either sold heifer or low producing milking cows and purchased high yielding cows were rejected for study purposes. In the selected farms, only crossbred Friesian × Shahiwal dairy cows weighing between 250-400 kg and having in between mid (101-200 days in milk) to late (201-300 days in milk) lactation were selected for study purposes. Primiparous, dry or multiparous milking cows in early lactation were rejected. BCS of experimental cows was recorded in a 1-5 scale.

In all selected farms, milk yield sharply increased in early lactation (1-100 d) which masked the influence of dietary metabolizable energy (ME) and crude protein (CP) intake on milk yield and milk composition. In mid lactation, milk production was almost steady which gradually declined during late lactation. Therefore, daily intake of roughage and concentrate were measured from mid to late lactation. Feed samples were subjected to proximate analysis. Since all farms used TMR, therefore, daily intake of ME was estimated from TMR as per Boguhn *et al.* (2003). Milk samples were collected from individual selected cows having same BCS during morning and evening and mixed together by a manual stirrer. Milk samples were immediately sent to the laboratory for preservation. Approximately 500 mL of composite milk samples were taken in a plastic container, stored in an ice box and immediately sent to the laboratory for chemical analysis. Feed and milk samples were collected and analyzed weekly. Chemical analyses of milk samples were carried out in triplicate for fat, protein, lactose, ash, total solids (TS) and solids not fat (SNF) in the dairy science laboratory, Chittagong veterinary and animal sciences university, Chittagong, Bangladesh as per AOAC (1994). Feed samples were weekly analyzed for moisture, crude protein (CP), crude fibre (CF), nitrogen free extract, ether extract and ash in the animal nutrition laboratory, Chittagong, Bangladesh as per AOAC (1994). Data related to ME intake, CP intake, milk yield, fat, protein, lactose, ash, TS and SNF content of milk were compiled by using Microsoft Excel 2007. One way analysis of variance was performed to find out the difference of ME and CP intake and milk measures and their combinations among selected farms. Principal components analysis was carried out to explore the strength and type of relationship between ME and CP intake and milk measures throughout mid to late lactation by using SPSS (2007) and Stata (2009) for correlation and single regression analysis. In the exploratory analysis, ME intake was calculated as MJ/d, CP intake g/d and the milk measures were in percentage. Statistical significance was accepted at 5% level ($P<0.05$).

RESULTS AND DISCUSSION

Averages form ME and CP intake and milk measures are shown in Table 1. ME intake (MJ/d), CP intake (g/d), milk yield, fat, protein, lactose, TS, SNF and ash content of milk significantly ($P<0.01$) differed among selected farms. Multiple correlation coefficient matrix indicated that, either ME or CP intake significantly ($P<0.01$) influenced only milk yield, milk fat and TS percent of milk (Table 2). It was further evident that, milk yield was positively correlated with both ME and CP intake. However, there was a negative association between ME intake, fat, protein, lactose, TS and SNF percent of milk even though the strength of relationship was variable. Similar to ME, CP intake was also negatively correlated with milk fat, protein, lactose, TS and SNF percent of milk. The reverse relationship between milk yield and TS percent of milk is likely phenomena. Therefore, it could be assumed that, as the level of ME and CP intake increased, fat, protein, lactose, TS and SNF content of milk decreased in the same order.

Milk is synthesized in the mammary gland mostly from dietary nutrients. Therefore, providing highly digestible forages, maximizing dry matter intake, adequate amounts of soluble sugar and degradable protein could be an effective way for manipulating milk composition. It was evident that, supplementing cows with concentrates increased 270-d milk yield, milk yield at peak and the height of the lactation profile for milk yield (Roche *et al.* 2006). The observed increase in milk yield with increasing concentrate supplementation has been reported elsewhere also (Kennedy *et al.* 2003). It was also evident that, the response to concentrate was comparatively higher in cows having superior genetic merit, particularly for milk production (Kennedy *et al.* 2002). These observations are in line with present study where increased ME intake by increasing concentrates in the TMR resulted higher milk yield (Table 2). From Figure 1, the response to one additional MJ consumed by a crossbred Holstein × Shahiwal dairy cow in mid to late lactation was 0.068 kg of milk per day. In another study, adding fat to energy deficient diets for lactating cows increased milk and protein yield, but decreased milk protein percent (Wu and Huber, 1994).

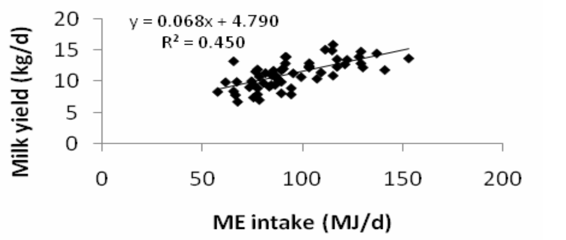

Figure 1 Relationship between ME intake and milk yield in crossbred dairy cows

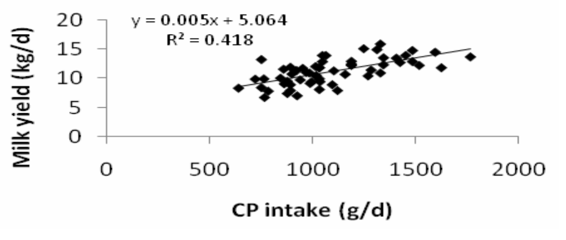

Figure 2 Relationship between CP intake and milk yield in crossbred dairy cows

In the current study, higher dietary ME and CP intake gradually decreased milk protein percent, but the correlation coefficient was not significant (Table 2).

Table 1 Average values of dietary ME (MJ/d) and CP (g/d) intake on milk yield (kg/d), milk fat (%), protein (%), lactose (%), ash (%), TS (%) and SNF (%) in crossbred dairy cows (N=120) from analyzed dairy farms

Name of the selected farm	ME intake (MJ/d)	CP intake (g/d)	Milk yield (kg/d)	Fat (%)	Protein (%)	Lactose (%)	TS (%)	SNF (%)	Ash (%)
Azizia dairy farm	103.20	1840.00	12.52	3.71	3.25	4.28	12.04	8.33	0.80
Bhuiyan dairy farm	75.40	1320.00	9.59	4.25	3.44	4.66	13.24	8.99	0.89
Janata dairy farm	129.00	2300.00	14.85	3.21	3.17	4.39	11.53	8.32	0.75
Jane Alam	89.30	1580.00	11.90	3.50	2.86	3.97	11.13	7.63	0.80
Jarif dairy farm	103.20	1840.00	12.24	3.16	3.33	4.32	11.58	8.42	0.77
Liza dairy farm	74.34	1319.60	9.00	4.18	3.41	4.69	13.10	8.92	0.82
Belal dairy farm	88.30	1550.00	10.00	4.14	3.26	4.50	12.77	8.63	0.87
Mollah dairy farm	103.20	1840.00	13.40	3.50	3.42	4.42	12.03	8.53	0.69
Raja-Badsha dairy	80.35	1390.00	9.82	4.95	3.40	4.57	13.60	8.65	0.68
Samiya dairy farm	129.00	2300.00	12.95	3.08	3.23	4.61	11.86	8.78	0.94
Bandhan dairy farm	84.35	1510.00	11.10	3.02	2.85	4.04	10.77	7.75	0.86
Mainudin dairy farm	75.40	1320.00	7.50	4.09	3.60	4.53	13.33	9.24	1.11
Average	94.59	1675.80	11.24	3.73	3.27	4.42	12.25	8.52	0.83
SEM	2.80	49.48	0.28	0.08	0.04	0.04	0.12	0.07	0.02
Sig.	**	**	**	**	**	**	**	**	**

CP: crude protein; TS: total solids and SNF: solids not fat.
SEM: standard error of means and NS: non significant.
** (P<0.01).

Table 2 Correlation coefficient matrix of ME intake (MJ/d), CP intake (g/d), milk yield (kg/d), milk fat (%), protein (%), lactose (%), ash (%), TS (%) and SNF (%) in crossbred dairy cows (N=120)

Parameters	ME	CP	MY	Fat	protein	Lactose	Ash	TS
ME	1	-	-	-	-	-	-	-
CP	0.99**	1	-	-	-	-	-	-
MY	0.67**	0.71**	1	-	-	-	-	-
Fat	-0.48**	-0.52**	-0.63**	1	-	-	-	-
Protein	-0.139	-0.138	-0.280*	0.40**	1	-	-	-
Lactose	-0.092	-0.106	-0.256*	0.41**	0.46**	1	-	-
Ash	-0.139	-0.158	-0.49**	0.004	0.066	0.137	1	-
TS	-0.39**	-0.42**	-0.62**	0.87**	0.69**	0.71**	0.196	1
SNF	-0.161	-0.173	-0.41**	0.44**	0.81**	0.84**	0.36**	-0.82**

ME: metabolizable energy; CP: crude protein; MY: milk yield; TS: total solids and SNF: solids not fat.
* (P<0.05) and ** (P<0.01).

Macleod *et al.* (1983) observed that, when rapidly fermentable carbohydrate was fed, greater amount of propionate and microbial protein was produced, leading to signals in the cow's body to produce more milk and milk protein. It was also observed that increasing energy intake of cows by decreasing the forage: concentrate ratio increased milk yield, milk protein and lactose but decreased fat content. This observation is in agreement with the present study where increased ME intake by decreasing the forage: concentrate ratio increased milk yield and decreased milk fat percent (Figures 1 and 3). Protein percent in milk even though decreased, but total protein yield increased as milk yield increased simultaneously (Figures 2 and 4).

In agreement with a number of observations (Gordon, 1977; Yousef *et al.* 1970) it could be reasoned that, increasing the proportion of concentrate resulted an increase in the energy density of the diet, which ultimately influenced microbial growth and capture of more degraded N which yielded increased total milk protein content. In another study Gordon (1977) also reported that, milk protein can be increased up to 0.4% or more if forage proportion in the diet was reduced to 10% or less of the dietary dry matter.

However, it is difficult to categorize the response of a greater proportion of concentrate on milk protein since effects are not independent of energy intake. In fact, estimates of the effects of forage: concentrate ratio on milk protein content may be confounded by dietary the energy intake. In our study, increasing dietary energy by reducing forage: concentrate ratio increased total protein yield, but decreased milk protein percent (Table 2).

Although evidences suggest that increasing energy intake through allocation of concentrates increases the protein content of milk, there are reported to the contrary. For example, Sutton *et al.* (1987) observed no change in protein content of milk with increased concentrate feeding. Gordon and Forbes (1970) reported that, milk protein tended to increase with increasing energy intake with a low protein diet but not with a high protein diet. In another work (Gordon, 1977), increasing both energy and protein intake increased SNF and protein contents of milk, but fat, lactose and ash were not altered. Grainger and Wilhelms (1979) altered energy intake by restricting pasture forage intake. It was observed that, cows fed at *ad libitum* increased milk protein content compared with cows fed at a restricted intake. In another study, Sporndly (1989) reported that neither NDF intake nor NDF concentration in the diet was related to milk protein content, because when the effects of energy

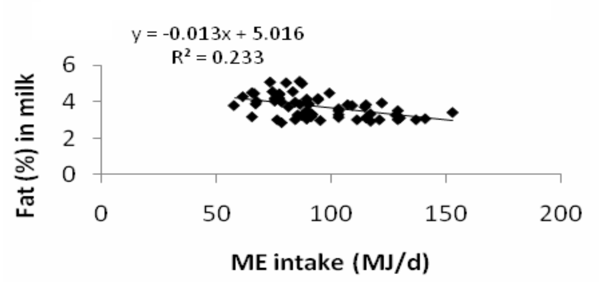

Figure 3 Relationship between ME intake and milk fat content in crossbred dairy cows

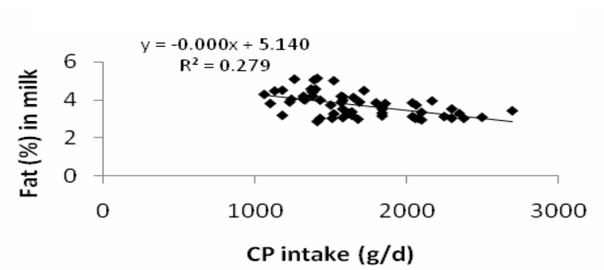

Figure 4 Relationship between CP intake and milk fat content in crossbred dairy cows

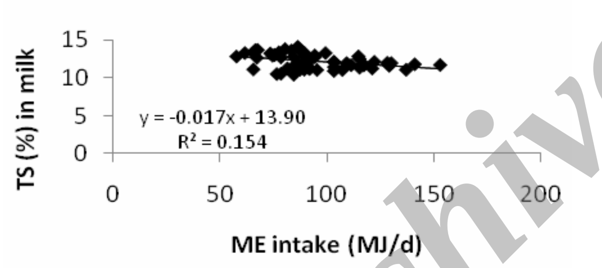

Figure 5 Relationship between ME intake and milk TS content in crossbred dairy cows

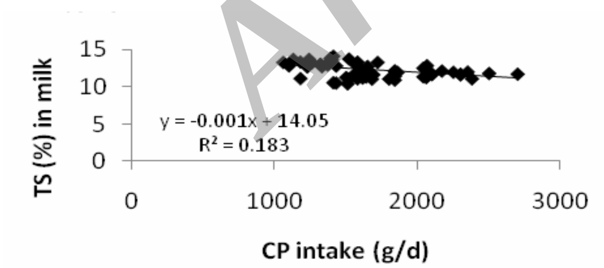

Figure 6 Relationship between CP intake and milk TS content in crossbred dairy cows

and protein intake were removed, the dietary concentration of roughage was not correlated to the concentration of milk protein. Similarly, Evans *et al.* (1975) fed low roughage and high roughage diets at similar digestible energy intake and observed no significant differences in daily milk yield and contents of fat and lactose. From the above discussion, it may be predicted that milk protein concentration is not influenced either by roughage: concentrate ratio or by proportion of NDF in the forages. Because, as the proportion of roughage increases in the diet, NDF also increases in the same manner. In the current study, dietary ME was increased by decreasing the proportion of dietary forage. As the cows were fed energy deficient diet, therefore, increasing ME intake increased milk yield followed by a decrease in protein percent of milk.

Effects of diet on the protein composition of milk are not always consistent. Some reports indicate no change (Roffler *et al.* 1978) or an increase (Holter *et al.* 1982) in milk protein content while the CP concentration of the diet is increased. Therefore, Grieve *et al.* (1986) suggested that the ratio of milk fat: protein is the actual indicator because fat and protein content often respond in opposite directions to dietary manipulation (Emery, 1978). In the present study, fat and protein percent in milk responded in opposite directions to dietary manipulation (Figure 3 and 6). Rook (1961) reported that, increasing the protein concentration above requirements had no effect on yield or composition of milk except that NPN content increased. However, the type of dietary protein can influence the protein content of milk (Thomas and Chamberlain, 1984). Emery (1978) reported that the protein content of milk increased up to 0.02% for each 1% increase in dietary CP when CP was not derived from urea. Sporndly (1989), in contrast, observed no significant correlation between protein content of milk and protein concentration of the diet. It was evident that by increasing the undegradable dietary protein level from 29 to 56 per cent of the total CP in the concentrate mixture of crossbred lactating cows, fat and protein content in milk increased (Chaturvedi and Walli, 2001). In this study influence of the type of protein was not investigated. However, increasing amounts of protein intake consistently increased milk yield decreasing protein percent, but this could be associated with a high correlation between CP intake and ME intake (Table 2).

CONCLUSION

ME intake significantly influenced milk yield, milk fat and TS percent of the milk in crossbred Holstein × Shahiwal dairy cows while energy deficient diet was offered. Similar to ME, CP intake also influenced milk yield, milk fat and TS content of milk in protein deficient diet. Milk yield was positively correlated with ME and CP intake in energy and protein deficient diet respectively. However, there was a negative association between ME or CP intake, milk protein, lactose, TS, SNF and specific gravity of milk. It could therefore be inferred that, adequate ME and CP intake is important to optimize milk yield and milk composition in crossbred dairy cows reared under intensive farming systems in tropical regions.

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