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

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Received on: 10 Oct 2013
Revised on: 17 Dec 2013
Accepted on: 30 Dec 2013
Online Published on: Dec 2014

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Online version is available on: www.ijas.ir

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. There-
fore, 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. High yielding Holstein-Friesian dairy cows reared mostly under pasture based feeding systems in temperate regions.

Friesian X Shahiwal 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 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 (Eichhornia craminipes) 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 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 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 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 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 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 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 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 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 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 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 and their combinations among selected farms.
The dietary energy and protein composition of milk is critical for optimal production and quality. Macleod et al. (1983) observed that, when rapidly fermentable carbohydrate was fed, greater amounts of propionate and microbial protein were produced, leading to signals of increased ME intake by decreasing the forage: concentrate ratio increased milk yield and decreased milk fat content. This observation is in agreement with the present study where increased ME intake by decreasing the forage: concentrate ratio increased milk yield, milk protein, and lactose but decreased fat content. 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

### Influence of Dietary Energy and Protein on Yield and Composition of Milk

**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

<table>
<thead>
<tr>
<th>Name of the selected farm</th>
<th>ME intake (MJ/d)</th>
<th>CP intake (g/d)</th>
<th>Milk yield (kg/d)</th>
<th>Fat (%)</th>
<th>Protein (%)</th>
<th>Lactose (%)</th>
<th>TS (%)</th>
<th>SNF (%)</th>
<th>Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azizia dairy farm</td>
<td>103.20</td>
<td>1840.00</td>
<td>12.52</td>
<td>3.71</td>
<td>3.25</td>
<td>4.28</td>
<td>12.04</td>
<td>8.33</td>
<td>0.80</td>
</tr>
<tr>
<td>Bhuian dairy farm</td>
<td>75.40</td>
<td>1320.00</td>
<td>9.59</td>
<td>4.25</td>
<td>3.44</td>
<td>4.66</td>
<td>13.24</td>
<td>8.99</td>
<td>0.89</td>
</tr>
<tr>
<td>Janata dairy farm</td>
<td>129.00</td>
<td>2300.00</td>
<td>14.85</td>
<td>3.21</td>
<td>3.17</td>
<td>4.39</td>
<td>11.53</td>
<td>8.32</td>
<td>0.75</td>
</tr>
<tr>
<td>Jane Alam</td>
<td>89.30</td>
<td>1580.00</td>
<td>11.90</td>
<td>3.50</td>
<td>2.86</td>
<td>3.97</td>
<td>11.13</td>
<td>7.63</td>
<td>0.80</td>
</tr>
<tr>
<td>Jarif dairy farm</td>
<td>103.20</td>
<td>1840.00</td>
<td>12.24</td>
<td>3.16</td>
<td>3.33</td>
<td>4.32</td>
<td>11.58</td>
<td>8.42</td>
<td>0.77</td>
</tr>
<tr>
<td>Liza dairy farm</td>
<td>74.34</td>
<td>1319.60</td>
<td>9.00</td>
<td>4.18</td>
<td>3.41</td>
<td>4.69</td>
<td>13.10</td>
<td>8.92</td>
<td>0.82</td>
</tr>
<tr>
<td>Belal dairy farm</td>
<td>88.30</td>
<td>1550.00</td>
<td>10.00</td>
<td>4.14</td>
<td>3.26</td>
<td>4.50</td>
<td>12.77</td>
<td>8.63</td>
<td>0.87</td>
</tr>
<tr>
<td>Mollah dairy farm</td>
<td>103.20</td>
<td>1840.00</td>
<td>13.40</td>
<td>3.30</td>
<td>3.42</td>
<td>4.42</td>
<td>12.03</td>
<td>8.53</td>
<td>0.69</td>
</tr>
<tr>
<td>Raja-Badsha dairy</td>
<td>80.35</td>
<td>1390.00</td>
<td>9.82</td>
<td>4.95</td>
<td>3.40</td>
<td>4.57</td>
<td>13.60</td>
<td>8.65</td>
<td>0.68</td>
</tr>
<tr>
<td>Sanniya dairy farm</td>
<td>129.00</td>
<td>2300.00</td>
<td>12.95</td>
<td>3.02</td>
<td>2.85</td>
<td>4.04</td>
<td>10.77</td>
<td>7.75</td>
<td>0.86</td>
</tr>
<tr>
<td>Bandhan dairy farm</td>
<td>84.35</td>
<td>1510.00</td>
<td>11.10</td>
<td>3.02</td>
<td>2.85</td>
<td>4.04</td>
<td>10.77</td>
<td>7.75</td>
<td>0.86</td>
</tr>
<tr>
<td>Average</td>
<td>94.59</td>
<td>1675.80</td>
<td>11.24</td>
<td>3.08</td>
<td>2.83</td>
<td>4.04</td>
<td>11.86</td>
<td>8.78</td>
<td>0.94</td>
</tr>
</tbody>
</table>

**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)

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

**Notes:** CP: crude protein; TS: total solids and SNF: solids not fat. SEM: standard error of means and NS: non significant.

**P** (<0.01) and **P** (<0.001).

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.
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

\[ y = -0.013x + 5.016 \]
\[ R^2 = 0.233 \]

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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REFERENCES


