Effect of Fishmeal Supplementation on Milk Yield of Holstein-Friesian Cows in Eritrea

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Abstract

A feeding experiment was carried out to determine the effect of supplementing the existing diet for dairy cows on a semi-government owned farm in Eritrea (Elabered Estate), with varying amounts of fishmeal that was locally produced by sun-drying and grinding. The experiment consisted of a two-week pre-experimental period followed by 90 days of experimental period. Forty primiparous Holstein cows, which had been milking for an average of 77 days, were placed into four groups of 10 each Group I to IV). The basal diet consisted of fresh alfalfa, grass hay, fodder maize, wheat middlings, wheat bran and wet brewer's grains to make 23.2, 19.9, 14.9, 15.8, 15.4 and 10.8% by weight on dry matter basis. This diet was offered throughout the experiment to cows in Group IV as the control diet and to all groups in the pre-experimental period. Cows in Groups I, II, and III received the same basal diet supplemented with 100, 200 and 300 g of fishmeal, respectively, in the experimental period. The cows were fed in a restricted manner. Crude protein (CP), crude fiber (CF), ether extract (EE), Ca, and P, given as % of dry matter, and ME (MJ/kg dry matter) of the control diet was 13.7, 23.1, 2.7, 0.62, 0.47 and 9.72, respectively. With fishmeal supplementation, the CP content of the diets fed to cows in Groups I, II, and III increased to 14.0, 14.2 and 14.5%, respectively. Milk yield of cows after adjusting for the pre-experimental milk yield were 13.84, 13.32, 13.29 and 12.98 kg/day for cows in Groups I, II, III and IV, respectively. Supplementation with 100 g of fishmeal per cow per day resulted in the highest milk yield compared to the control (P=0.055). The 200 and 300 g of fishmeal supplementation did not increase the milk yield further, possibly due to the high protein content of the control diet.

Key words: Dairy cows, fishmeal, supplementation, milk yield

Introduction

Rumen undegradable protein from protein supplements such as fishmeal, becomes more and more important as milk production per cow increases (Kaufmann, 1982). Fishmeal is a rich source of all the essential amino acids (O'Connor *et al.*, 1993) including lysin and methionine that are probably the most important limiting amino acids for milk production and milk protein synthesis in high producing animals (King *et al.*, 1990). Cows producing up to 4,500 kg per lactation could meet all their protein requirements from microbial protein (Virtanen, 1966). In the tropics, usually even dairy breeds of European origin do not exceed this level of production because of the effect of high environmental temperatures and the quality of the feeds (Breinholt *et al.*, 1981; Martínez *et al.*, 1982; Vaccaro and de Vaccaro, 1982; Parker, 1984). However, increasing the supply of protein to the small intestine can also be beneficial to cows that are under heat stress and fed on high roughage diets (Parker, 1984).

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The importance of fishmeal is not only limited to the part that escapes rumen fermentation. Fishmeal is also rich in protein that is degraded slowly in the rumen (ARC, 1980) and the slow release of N is believed to enhance fiber digestibility (Kabre and Petit, 1994; Smith and Oldham, 1982). The rumen degradable portion of fishmeal increases with lower rates of passage (McDonalds, 1995). This could make it useful under tropical conditions where particle residue time in the rumen is longer than in mixed forage-concentrate diets from which values for degradabilities are normally obtained (McAllan, 1991). In addition, fishmeal is a good source of minerals such as Ca, P, Se, and I, the B-complex vitamins and fat, depending on the raw material or species of fish (FAO, 1986; McDonalds, 1995).

Shortage of high quality protein supplements is a constraint that in general is limiting animal production in many African countries. A limited amount of oil seed cakes, flour mill by products, such as wheat bran and wheat middlings, and wet brewer's grains is available, but the demand for these products is often much greater than the supply. Fishmeal is a high quality protein source that Eritrea has an unexploited potential to produce (Aubray, 1975). It has, therefore, the potential to help alleviate the protein shortage that currently affects Eritrea's livestock. Locally produced fishmeal has been shown to have similar nutrient composition to imported fishmeal (Steiner-Asiedu, *et al.*, 1993; Eid *et al.*, 1992; Lim *et al.*, 1989).

The objective of the present experiment was to examine the effect on milk yield of supplementing Holstein-Friesian cows with varying amounts of fishmeal. The fish meal was made from by-catch fish from shrimp production as well as fish waste from urban fish markets, which was sun-dried and grinded.

Materials and Methods

The study was conducted in a semi-government owned institution (Elabered Estate), that has more than 300 lactating Holstein-Friesian cows. This is also the largest farm in Eritrea. The farm has an elevation of about 1500 metres above sea level, and experiences high temperatures of about 30°C during the day almost throughout the year. The estate has enough water and land to provide fresh alfalfa and fodder maize grown by irrigation to the cows throughout the year. Good quality hay made mainly from *Hyparrhenia rufa* is also available for the cows, while the concentrate supplements are purchased.

Cow management and experimental design

The animals were housed in a shaded, concrete-floored corral and maintained in a system of zero-grazing fed with freshly cut forages, hay and agro-industrial by-products as concentrates. They were untied and allowed to exercise within the corral for about 1.5 hours daily after morning milking.

Forty primiparous Holstein-Friesian cows that had been milking for an average of 77 days were placed into four groups after balancing for date of calving, milk production and body weight estimated by heart girth measurement. Days in milk were 81, 68, 78, and 80 days for Groups I, II, III and IV, respectively. Feed was provided in a restricted manner, with concentrate being offered twice a day after milking. Fodder maize and alfalfa were offered consecutively after the concentrates. Grass hay was offered after afternoon milking. The animals in all the groups were provided the same diet for the two-week pre-experimental period. The diet consisted of fresh alfalfa, grass hay, fodder maize, wheat middlings, wheat bran and wet brewer's grains to make 23.2, 19.9, 14.9, 15.8, 15.5 and 10.8% by dry matter weight basis. In the three months of the experimental period, fishmeal was incorporated to the ration of the cows in Groups I, II and III at 100, 200 and 300 g/day. The fishmeal was offered mixed with the concentrates. About 70 grams (0.5% of ration DM) of common salt (NaCl) was provided per cow per day. The cows had access to water at all times. The water was collected in reservoirs during the rainy season, from a nearby river, and stored for use through the long dry season. Milking was done by hand twice a day starting at 4:00 am for the morning milking and 4:00 pm for the afternoon milking. The milk yield of each cow was recorded twice daily. Heart girth measurements of all cows were taken every second week to estimate weight gain.

Dry matter digestibility Trial

Even though there were no metabolic crates for the proper collection of faeces and urine, a trial was carried out for a period of seven days towards the end of the experimental period to estimate the dry matter (DM) digestibility of the rations of the different groups. Two cows were used from each treatment group. The total amount of the feed offered and refused was weighed, and the difference used to estimate the intake. The total faeces of the cows was also collected and weighed. Samples of the feeds offered and refused, and the faeces, were dried in an oven at 102°C to determine the dry matter. The DM digestibility was determined according to the equation:

$$\text{DM digestibility} = \frac{\text{Dry matter intake} - \text{Faeces dry matter}}{\text{Dry matter intake}}$$

Chemical analyses

Samples of the diets were collected at regular intervals. The contents of crude protein (Kjeldahl-N x 6.25), crude fat (HCl-ether extract), crude fibre, ash, calcium and phosphorus were determined according to standard procedures described by Association of Official Analytical Chemists (AOAC) (1990).

Statistical analysis

The trial was designed according to a completely randomised design, with each cow as the experimental unit. Daily milk yield was analysed using the GLM procedure of the SAS Institute, Inc. (1990). Results are presented as the least square means (LSMEANS) of each treatment group after adjusting for pre-experimental milk yield as a covariate, and variance of the data is presented as standard error of the means (SEM). Milk records of cows that suffered from mastitis and anaplasmosis during the experimental period were not included in the analysis. The records of two cows in Group II that were in a more advanced stage of lactation during the experimental period, and gave consistently lower yields, were excluded from the analysis.

Results

Chemical analysis of rations

The ingredients and chemical analysis of rations are shown in Table 1. The inclusion of fishmeal to the rations increased the crude protein content from 13.7% in the control diet to 14.0%, 14.2% and 14.5%, respectively, for rations of groups I, II and III. Calcium, phosphorous and ether extract content also increased with increasing inclusion of fishmeal. The calculated energy content showed an increase with increased inclusion of fishmeal.

Table 1. Diet components and chemical composition (% of DM)

Item	Fishmeal supplemented groups			Control group
	Group I	Group II	Group III	Group IV
Ingredients, % of diet				
Alfalfa	23.08	22.94	22.80	23.22
Grass hay	19.76	19.66	19.56	19.92
Fodder maize	14.78	14.69	14.61	14.87
Wheat middling	15.65	15.56	15.46	15.75
Wheat bran	15.38	15.29	14.86	15.48
Wet brewers' grains	10.70	10.64	10.58	10.77
Salt	0.50	0.50	0.50	0.50
Fishmeal	0.61	1.21	1.80	-
Dry matter intake, kg	14.95	15.04	15.13	14.86
Chemical composition				
Crude protein, %	13.96	14.22	14.47	13.69
Crude fiber, %	22.96	22.82	22.68	23.10
Ether extract, %	2.69	2.72	2.74	2.67
Ca, %	0.70	0.77	0.84	0.62
P, %	0.48	0.49	0.50	0.47
ME (MJ/kg), calculated	9.79	9.86	9.94	9.72

Table 2. Daily intake of various nutrients, compared to NRC recommendations

	Group I	Group II	Group III	Group IV	NRC (1988) Recommendation
ME[1] (MJ)	146.36	148.29	150.39	144.44	148.04
Crude protein, g	2087.37	2138.74	2190.11	2036	1896.25*
Degraded intake protein[1], g	1388.33	1408.88	1429.43	1367.78	1163.5*
Undegraded intake protein[1], g	699.04	729.86	760.68	668.22	735.75*
Ca, g	104.65	115.81	127.09	92.13	69.75

[1] Calculated using textbook values.

*Recommendations valid for a 500 kg cow, growing at 0.275 kg per day and producing 15 kg of milk (Approximate weight of experimental cows was 450 kg)

Nutrient intake

Average dry matter intakes for Groups I, II, III and IV were 14.95, 15.04, 15.13 and 14.86 kg per day. All cows had similar DM intakes because almost invariably all cows consumed all feed offered except during the days when a cow was sick. The intake of metabolizable energy (ME), crude protein (CP), degraded intake protein (DIP), undegraded intake protein (UIP) and Calcium (Ca) is shown in Table 2.

Dry matter digestibility

Dry matter digestibility were 57.9, 61.0, 64.6 and 56.4% for Groups I, II, III, and IV, respectively, the difference not being statistically significant ($P = 0.44$). The apparent DM digestibility is shown in Table 3.

Milk yield

During the pre-experimental period, cows in all groups had similar average milk yields per day, 14.70, 14.80, 14.75, and 14.29 kg for Groups I, II, III, and IV, respectively. The average daily milk yield for the experimental period was 13.87, 13.40, 13.35, and 12.81 kg for Groups I, II, III and IV, respectively. After adjusting for the pre-experimental milk yield as a covariate, the average daily milk yield of the experimental period was 13.83, 13.32, 13.29, and 12.98, for Groups I, II, III, and IV, respectively.

As shown in Table 3, cows supplemented with 100 g of fishmeal (Group 1) produced 0.85 kg of milk per day higher than the control group (P=0.055). The milk yield for each week in the trial of the cows in the four groups is shown in Figure 1. After three weeks into the experimental period, milk yield of all the groups decreased for three weeks, the decrease being most marked for Group III and Group IV. Milk yield then started to increase for the fishmeal-supplemented groups, but not for the control group (GroupIV).

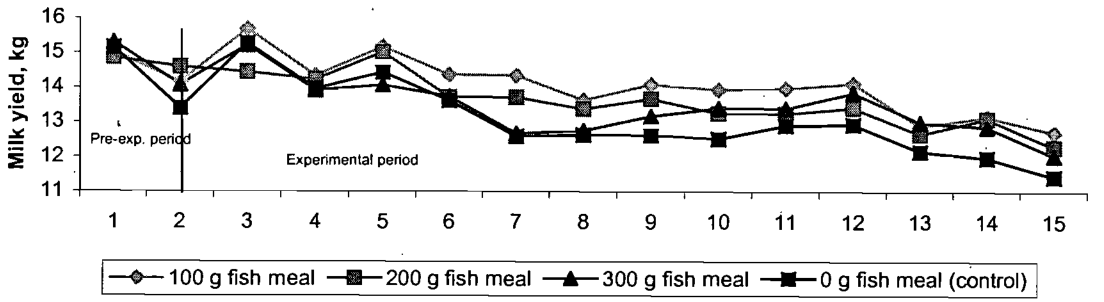

Figure 1. Weekly milk yield of Holstein-Friesian cows supplemented with varying amounts of fishmeal on a control diet consisting of fresh alfalfa, fodder maize, grass hay, wheat middlings, wheat bran and wet brewers' grains.

Table 3. Milk yield and DM digestibility of cows fed the control- and fishmeal- supplemented diets

	Group I[1]	Group II[1]	Group III[1]	Group IV[1]	P-value	SEM[2]
Number of cows	10	8	10	10		
Milk yield, kg/d						
Pre-experimental [3]	14.70[a]	14.80[a]	14.75[a]	14.29[a]	0.71	0.41
Experimental[4]	13.87[a]	13.40[ab]	13.35[ab]	12.81[b]	<0.05	0.29
Adjusted milk yield[5]	13.83[a]	13.32[ab]	13.29[ab]	12.98[b]	0.055	0.31
Adjusted milk yield, 1st mo.	14.68[a]	14.14[a]	14.06[a]	14.45[a]	0.16	0.31
Adjusted milk yield, 2nd mo.	13.95[a]	13.39[a]	13.31[a]	12.87[a]	0.06	0.41
Adjusted milk yield, 3rd mo.	13.27[a]	12.82[ab]	12.90[ab]	12.28[b]	0.04	0.33
App. DM Digestibility, %	57.89[a]	60.96[a]	64.57[a]	56.36[a]	0.44	22.92
Daily body weight gain (kg)	0.29[a]	0.28[a]	0.30[a]	0.37[a]	0.76	0.05

[1]Cows in Groups I, II, III supplemented daily with 100, 200, 300g of fishmeal, respectively. Group IV was control
[2] Standard error of the mean
[3] For 14 days prior to starting the trial
[4] For 90 days of the trial
[5] Mean milk yield obtained after adjusting for pre-experimental yield as a covariate
[ab]Means in the same row not sharing a common superscript are significantly different (P<0.05)

Body weight gain

Daily body weight gain estimated by heart girth measurements were 0.29, 0.28, 0.30 and 0.37 kg for Groups I, II, III, and IV, respectively, the difference being not significant (P=0.76) (Table 3).

Discussion

Feed intake

The DM intake of cows in all treatment groups was about 15 kg per day per cow. The cows consumed all the feed they were offered. The

NRC (1988) indicates a dry matter intake if 13.5 kg per day for a cow weighing 450 kg and producing about 15 kg of milk per day. The higher feed intake of the cows in the present study could be due to the lower energy density of the rations and perhaps due to a higher maintenance requirement due to heat stress. Taylor *et al.*, (1991) found higher feed intakes for uncooled cows than for cooled cows, even though the cooled cows were more efficient in conversion of feed to milk. It was not possible to see any intake reducing effect due to heat stress, because all treatment groups were under restrictive feeding.

ME requirement of the cows under heat stress versus the supply

The calculated intake of ME per day for the cows without supplementation of fishmeal was about 144.39 MJ. The ME requirement per day of a growing lactating cow in first lactation producing 15 kg of milk with 4.0% fat is 143.68 MJ (NRC, 1988).

The energy provided by the control ration could have been adequate if the cows were in a thermo-neutral zone. However, the conditions at the experimental site in Eritrea during the months of April to July, when the trial was carried out, were far from neutral. Minimum temperatures recorded for most of the days in the four months ranged from 12-15°C while maximum temperatures ranged from 33-35°C. Temperatures for most of the day were about 30°C or above. Moreover, as these months coincided with the rainly season, the relative humidity during most of the days was very high. The ME requirements for maintenance increase by 10 to 30% at 30 to 40°C, versus 18 to 20°C (NRC, 1981). Assuming the present heat-stress to increase the ME requirement for maintenance by 10%, the ME (MJ) per day to produce 15 kg of milk at 4% fat would be 148.04. At the beginning of the experiment all the cows in the different treatments were producing close to 15 kg of milk daily, while they were slightly limited by energy. This could have been possible due to mobilizing of body fat. As the trial continued beyond mid-lactation, the cows fed on the control diet, as well as the fishmeal supplemented cows, reduced milk production, and gained body weight instead.

Protein requirement and supply

While environmental stress has direct consequences on the dietary energy requirements of cattle, there is at present considerable uncertainty as to desirable adjustments for the non-energy components of diets (NRC, 1981). Higher CP levels are recommended for dairy cows in the humid tropics (warm climates) because of the belief that with lower intakes the cows will not obtain all the protein they need unless the concentration of the protein in the diets is higher. This was not a problem in the present study because the CP intake of the cows was even higher than the recommended intake. NRC (1988) recommends an intake of 1759g crude protein per day for a 450 kg cow producing 15 kg milk with 4 % fat. The diet of the control group provided 2036 g of CP per day while supplementation with fishmeal increased this up to 2087, 2139, and 2190 for each cow in Groups I, II, and III, respectively. It is evident that protein was not the limiting nutrient to milk yield, and supplementation with fishmeal further increased the protein content. Fishmeal supplementation, however, resulted in an increase in milk yield in all the supplemented groups compared to the control, with milk yield being highest in Group I with 100 g supplementation resulting in a 0.85 kg extra milk per cow per day compared to the control after adjusting for the pre-experimental milk yield. The main reason for higher milk yield with addition of fishmeal could be due to more protein exiting the rumen and thus improving the undegraded intake protein (UIP) content. The calculated undegraded intake protein (UIP) and degraded intake protein (DIP) of the control diet increased from 668 to 699 g and 1368 to 1388 g, respectively after supplementation with 100 g of fishmeal. NRC (1988) recommends 733 g of UIP and 1164 g of DIP per day for a 500 kg cow producing 15 kg of milk with 4 % fat and growing 0.275 kg per day. Taking the slightly smaller average weight (about 450 kg) of the cows used in the present study it can be seen that a 100 g fishmeal supplement was enough to meet the NRC recommendation for UIP, while there was an excess of DIP even with the control (unsupplemented) diet. This increased flow of amino acids to the duodenum of the cows could make more amino acids available for milk protein synthesis and/or helped a more efficient utilization of the available volatile fatty acids by providing amino acid carbon for glucose synthesis. It is known that diets that produce a higher molar proportion of acetate (high in roughage) are less efficiently used in terms of energy retention than those which produce a higher proportion of propionate (high in concentrate) (Blaxter, 1962). Protein content of different diets can affect energy retention of high roughage rations. MacRae and Lobley (1982) suggest that the poor utilisation of acetate on high roughage diets may be due to a lack of propionate to provide, via glucose, NADPH for lipid synthesis. In such a situation it is unlikely that excess protein is available to provide gluconeogenic precursors and therefore acetate is "wasted" in some form of futile cycle producing heat. Addition of fishmeal could have a positive effect on fiber digestion in the rumen. Oldham *et al.* (1979) found with dairy cow rations that replacement of urea by fishmeal increased digestibility of ration DM. Smith and Oldham (1982) replaced urea by fishmeal as a N supplement for steers and obtained a marked improvement in digestion of β-linked glucose and xylose in the rumen. Hespell and Bryant (1979) pointed out that although the rumen microbial population is able to scavenge ammonia at low concentrations, the concentration of amino acids needed for 50% maximal uptake rate in bacteria (about 100μM) exceed those generally in the rumen. They suggest that this may be a critical factor regulating growth and that slowly degraded proteins (e.g., fishmeal) might exert their beneficial influence on production not only, as is supposed commonly, by increasing undegraded dietary protein supply, but also by improving efficiency of microbial protein synthesis. Kabre and Petit (1994) found an increase in hay digestibility by fishmeal supplementation to undernourished ewes. Since they used hay with N supply that approximately satisfied the theoretical need of microorganisms, they argued that the increase in digestibility of the hay in the fishmeal supplemented ewes was due to a supply of some amino acids or amino acids-derived isoacids favouring microbial activity. Similarly, in the present study the slow release of the N of the degradable portion of fishmeal could have enhanced microbial activity in the rumen leading to increased digestibility of the roughages, which constituted 58% of the ration dry matter. The DM digestibility in the present study increased with increased levels of fishmeal supplementation. The reason that the difference in digestibility was not significant could be due to the low number of cows used and the variation between cows. The inability to collect the urine because of the absence of metabolic crates could not enable the determination of N lost in the urine which perhaps could have helped explain why increasing apparent digestibility of DM did not result in higher milk yield of cows in Groups II and III compared to Group I.

Increasing levels of fishmeal above 100 g/day did not result in increased milk yield even though both groups supplemented at 200 and 300 g fishmeal had slightly higher milk yields compared to the control. The reason for this could be that at these levels both the DIP and UIP were in excess of that required by the cows as can be seen in Table 2. This could have led to a decrease in energy supply because excess protein must be deaminated to ammonia and, for the most part, transformed back to urea for excretion (NRC, 1988). At high levels of protein intake conversion of excess absorbed N can incur an energy cost, which may be big enough to result in negative performance response to increased protein intake. The penalty paid by the animal for excessive protein intake is two-fold; first there is the additional energy cost of urea synthesis from excess protein N and second the increased energy output as urea in urine (Oldham and Alderman, 1982). Danfaer *et al.* (1980) found that milk yield decreased when protein intake increased beyond ~200 g CP/kg ration DM and the energy cost caused the fat corrected milk yield to fall by 1.4 kg/day when N intake increased by ~100 g/day. For the respective groups in the present study, mean N intakes in excess of requirements (NRC, 1988), estimated at the beginning of the experiment, averaged 30.6, 38.6, 47.0 and 22.4 g/d. Assuming an additional energy expenditure of 0.023MJ/g N (Martin and Blaxter, 1965), the 8.1 and 16.5 g/d more N consumed by cows in Groups II and III, respectively, than Group I would have accounted for 11 and 23% of the difference in milk energy produced. The energy contained in milk is assumed to be 3.1 MJ/kg for milk containing 4 percent milk fat (NRC, 1988). It should be noted that there was no statistically significant difference (P>0.22) between the three groups supplemented with fishmeal.

The decrease in milk yield for all groups that occurred three weeks into the experimental period might be related to a reduction in quality of the forages grown on the farm, but this was not recorded.

Milk protein and fat content could have been affected by fishmeal supplementation, but only milk yield was taken into consideration and it was assumed that the milk fat content was 4.0%. This is true for milk fat content of samples taken from the bulk milk sold by the farm to a milk processing plant. Higher milk protein and fat contents have been reported for cows fed fishmeal as a protein source compared to urea or soybean meal (Oldham *et al.*, 1985; Hussein *et al.*, 1991). It is possible that the cows provided with 200 and 300 grams of fishmeal could have produced milk with higher milk protein and fat contents than the cows provided with 100 g or the control.

The restricted type of feeding could have masked the effect of the higher levels of fishmeal supplementation. The main reason for the improvement in animal performance obtained by increasing CP levels in diets is through an increase in feed intake because of improvement in the digestibility of the ration (Oldham, 1984). Hassan and Roussel (1975) found significantly higher yield of 4% fat corrected milk in cows fed a diet with 20.8% than in cows fed a diet with a 14.8% CP, but the increase in milk production and 4% FCM was found to be associated with the increase in total feed and total digestible nutrients intake and not with crude protein intake. Sanderson et al (1992) found similar results of fishmeal inclusion on feed intake on growing. Restricting the feed intake and increasing the dietary protein concentration in the present study could have lead to an excess of protein, which had to be changed to urea for excretion at the cost of energy.

Effect of stage of lactation

At the beginning of the pre-experimental period the cows were just past their peak production with an average of 77 days post-partum. Milk yield of all groups of cows slightly decreased because of the advance in stage of lactation by the end of the experimental period. The stage of lactation could also have affected the response of the cows to the supplementation of fishmeal. Istasse et al., (1986) found a significant increase in milk yield in response to casein infusion on Friesian cows in early and late lactation. The response was significantly greater for the cows in early lactation than for those in late lactation. However, the protein and total solid yields increased for the cows in early lactation but did not significantly change in late lactation. The authors suggest that the lack of a significant increase in late lactation may be due to a reduction in the uptake of the amino acids by the mammary gland associated with a reduction in the extraction rate, because milk yield was lower. These authors found a marked rise in plasma insulin with increasing levels of casein infused in late lactation, but no such changes in early lactation. Glucose concentration did not change in both lactations. They explained the increase in plasma insulin in late lactation to be due to the stimulation of the endocrine pancreas by some amino acids in excess in the blood. The high insulinaemia associated with infusion of casein in late lactation explained the smaller response in terms of milk production, body tissue deposition being favoured instead of milk production, according to Istasse *et al.*, (1986). Similarly, in the present study, the cows put on body weight even though the milk yield was not very high. There was an excess of amino acids with the higher levels of supplementation, which could have been more utilised in body tissue deposition instead of milk production. If the experiment were carried out on cows in early lactation, possibly the amino acids from the higher levels of fishmeal supplementation would be extracted more rapidly and the effect on milk yield could be more positive.

Other components

The control diet provided an adequate amount of Ca and P with the right proportion. The amount of Ca and P in the control diet was about 94 and 70 g, respectively, per day per cow, which slightly exceeded the NRC (1988) recommendation of 70 and 45g of Ca and P, respectively, for cows with the weight and level of milk production as in the present study. Supplementation of fishmeal further increased the amount of Ca and P.

Feed samples were not analysed for minerals other than Ca, P and Mg. Calculated iodine (I) content of the control diet was 0.1mg/kg. Dietary iodine concentration of 0.6 mg/kg is recommended for high-producing lactating cows (Hartmans, 1974; NRC, 1988). The control diet could have been short in I as most of the components were grown in the compound, which is far from the sea and is a low rainfall area where the soils could be deficient in I. Long-term deficiencies of I may result in decreased milk yields (NRC, 1988). Supplementation with fishmeal slightly improved the I content to 0.12, 0.14, and 0.16 mg/kg in Groups I, II and III, respectively. About 70 grams (0.5% of ration DM) of common salt was provided daily for each cow. Calculated figures showed that other macro and trace minerals were adequately provided by the control diet.

Water quality

The water that was provided to the cows from the local reservoirs had a foul odour that could always be detected. This could have affected water intake and had an impact on production. The water intake could not be measured, and water analysis was not performed.

Economic considerations

Even though fishmeal is an expensive source of protein, whether to use it or not should be determined by weighing the extra benefit in terms of milk production, improvement of fertility, body condition, etc., against the cost of the fishmeal. At the time the trials were carried out, the cost of the locally produced fishmeal was 4.00 nakfa (0.4 USD) per kg and the wholesale price of 1kg of milk was 2.30 nakfa. As a result of supplementation with 100 g fishmeal, an extra 0.85 kg of milk was produced. The extra gain from the sale of the extra milk after covering the cost of the fishmeal was 1.55 nakfa per cow per day. However, there was a net loss of 0.02 and 0.51 nakfa, respectively per cow per day for Groups II and III compared to the control (Group IV) because of the higher inclusion of fishmeal in the ration.

Conclusions and Recommendations

Supplementing the current diet of the experimental herd (Elabered Estate) with 100 g of fishmeal significantly (P=0.055) improved milk yield and profitability of the cows. Considering that shortage of feed is a major constraint, the results of the experiment are relevant in recommending that there would be no economic benefit in supplementing above 100 g of fishmeal per cow per day. However, there were certain questions that the trial could not answer for, which further studies are needed. A similar trial is recommended with *ad lib* feeding to determine the effect of the higher levels of fishmeal supplementation on feed intake and milk yield. Supplementation should commence either immediately after calving or before calving to know the effect of stage of lactation and to see if the reproductive performance of the cows is improved as well. The animals at Elabered Estate are relatively much better fed than other animals in Eritrea, owned by private farmers. The trial was carried out in the estate partly because it was the only place in the country with appropriate facilities and sufficient number of similar animals to enable a feeding trial. Fishmeal supplementation would be expected to result in better performances in animals at other farms that are more limited by N deficiency than the cows used in the present study. Most of the Holstein-Friesian cows in Eritrea are found around the capital, Asmara, where the altitude of about 2300 meters above sea level considerably reduces the heat stress that affects the cows' performance in the present study. Fishmeal supplementation should therefore also be tested in a more thermo-neutral zone.

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