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RESEARCH ARTICLE

Effect of Different Levels of Dietary Bole (Lake Soil) Inclusion on Feed Intake, Milk Yield and Composition of Holstein Friesian Cows

*Shewangzaw Addisu[1], Firew Tegegne[2] and Zeleke Mekuriaw[3]

[1]Alage ATVET College, P.O.Box 77, Zeway; [2]Bahir Dar University, P.O.Box 26, Bahir Dar; [3]LIVES, ILRI-Bahir Dar

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***Corresponding Address:**
Shewangzaw Addisu
shewangzaw21@yahoo.com

ABSTRACT

The experiment was conducted with the objective of evaluating the effects of inclusion dietary bole soil at different levels on dry matter intake, milk yield and milk composition of Holstein Friesian cows. Sixteen, two to four multi-parious mid-lactation Holstein cows with milk yield of 10.5 ± 2.14 kg d^{-1} and 383.5 ± 35.44 kg average body weight were blocked based on their average milk yield. Cows were assigned to one of the four dietary treatments using RCBD. The treatments were T1= 0% Bole soil in the concentrate, T2= 1.5% Bole soil in the Concentrate, T3= 3% Bole soil in the Concentrate and T4= 4.5% Bole soil in the Concentrate. Grass hay was used as a basal diet. The trial was conducted for 60 days. Data were analysed by analysis of variance (ANOVA), general linear model (GLM) procedure of SAS (2002). Grass hay intake was significantly different (P<0.01) among treatments, the highest being T2. There was no significant difference (P>0.05) on concentrate intake among treatments. Total dry matter intakes were significantly different (P<0.05), with the highest record for T2. Crude protein and metabolizable energy intakes were not significantly different (P>0.05) among treatments where as intake of neutral detergent fiber, acid detergent fiber and ash were significantly different (P<0.05) among treatments with higher value for T2. Dietary treatments did not affect average daily milk yield of cows. Similarly, milk protein, solid not fat and total solid content were not significant different (P>0.05) among treatments. However, milk fat content and feed conversion efficiency were significantly different (P<0.05) among treatments, the highest being in T3. The 4% fat corrected milk yield of cows were significantly different (P<0.01) between treatments for T2=T3 > T1=T4. Therefore, from the present study, it can be conclude that inclusion of 1.5% bole soil with concentrate diet is recommended on biological response of lactating Holstein Friesian cows.

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INTRODUCTION

Ethiopia has a large livestock population and diverse agro-ecological zones. The major livestock feed resource base (green fodder or grazing lands) contributes 58.67%, crop residue 29.19%, improved feeds 0.25%, conserved hay 7.35%, agro-industrial by-products 0.83% and others 3.71% of the total supply (CSA, 2011). Based on these feed resources from the total livestock producer about 24.59% of the population are engaged in the dairy development package (Ibid). However, livestock production has mostly been subsistence oriented and characterized by very low reproductive and production performance (Adugna Tolera, 2008). Improving milk production and dairy development, therefore, is an important tool for improving household nutrition and income of the producers. However, to improve milk production seasonal inadequacy of the quantity and quality of available feed resource as well as mineral contents are the major problem facing dairy producers in Ethiopia (Zegeye Yigezu, 2003).

In the past years, one of the strategies to supply dietary minerals for dairy animals was to cover a high proportion of dairy animal requirement with a mineral mix with minimal or, in some cases, no consideration of mineral content in the other dietary ingredients, i.e. forages, grains and byproducts. Minerals can be incorporated into free-access feed blocks, which also provide a source of energy and nitrogen. Data from National Research Council (NRC) and mineral chemical analysis (mainly macro minerals) of the different dietary ingredients were also used to adjust mineral contents in dairy diets (NRC, 2005).

The two sources of minerals include natural feeds (forages and grains) and mineral supplements to balance the minerals present in the forages and grains. However, the bioavailability of minerals of common feeds is not well characterized and is affected by: intake level, feed type, variations of the same feed and interactions between mineral, soil fertilization, method of analysis, etc. (NRC, 2001). Plants and plant products form the main supply of nutrients to animals and the composition of plants will influence the animal's mineral intake (McDonald *et al.,* 2002).

McDonald *et al.* (2002) also stated that though energy and protein are of primary importance to any animals, optimal animal performance is possible only if there is an adequate supply of minerals and vitamins. In the Central Rift valley, Ca and P concentrations of the major feedstuffs except for some fodder trees and barley straw were low (Zewdi Wondatir, 2010) as compared to the recommendations. To this end, it is important to know the possible sources of essential minerals. The existing animal feed processing firms and dairy producers add limestone and common salt (NaCl) in concentrate mixtures as mineral source depending on availability (Nega *et al.,* 2006). A number of mineral soils that can be obtained from different parts of Ethiopian Rift Valley lakes and other areas contain adequate amount of most of the essential minerals with the exception of phosphorus (Adugna Tolera, 2008). These include Bole (*Lake Abaya, Abijata, Zeway and Shala*), Addo or Megadua (*L. Abaya*) and Red Soil. From these, Bole is abundantly and locally available in the Central Rift Valley than the other kinds of mineral soil and is used by local farmers as a mineral source for their cattle. Previous work showed that bole soil improves milk yield and feed intake of dairy cows (Nega *et al.,* 2006), however, there was no documented information on the level of intake and corresponding productivity. Therefore, this study was conducted with the objective to evaluate the effect of different levels of Bole (lake soil) on feed intake, milk yield and milk composition of Holstein Friesian cows.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Alage Agricultural Technical Vocational and Education Training (ATVET) College Dairy Farm from January to March 2013. The area is located at a distance of 217 km south of Addis Ababa, at an altitude ranging from 1580 to 1600 masl, at 07^0 42' N latitude and 38^0 28'E longitude in the agro-ecologically semi-arid Southwestern part of the Ethiopian mid Rift valley. The area receives an average annual rainfall ranging from 700 to 900 mm. The area has three distinct seasons, namely; main rainy (June to September), short rainy (March to May) and dry (October to February) seasons. The average maximum and minimum daily barn temperature were 32±1.88°C and 15.5±1.96°C respectively.

Experimental Feed Preparation and Feeding Management

The experiment was conducted for a period of 60 days following an adaptation period of 15 days. The experimental feed consisted of natural and native grass hay, concentrate feed and Bole (lake soil) as a mineral supplement. The grass hay was predominantly composed of Rhodes grass *(Chloris gayana*), Bermuda grass *(Cynodon dactylon*) and *Hyperrhenia rufa.* The commercially concentrated diet comprised noug (*Guizotia abyssinica*) seed cake (33%), wheat bran (54%), crushed maize grain (10%), ground limestone (2%) and common salt (1%). The dried bole soil used for the present study was collected from Lake Shalla. The soil was mixed with the formulated concentrate diet at different levels (1.5, 3 and 4.5%) based on the work of Nega *et al.* (2006) who used 3% bole soil. The mineral soil was mixed based on the recommendation of Lawrence (2012), who recommended that minerals are best fed mixed with other feeds (force fed).

The experimental supplement was offered at the rate of 0.5 kg per 1 kg of milk with a 4% butter fat content (NRC, 1989) in two equal feedings before the morning and evening milking. Hay was fed *ad libitum.* The cows were fed individually in tie stall in a well-ventilated barn with concrete floor. Water was offered free access from automatic drinker throughout the day except the time from 08:00 to 14:00 hours. The cows were fed the basal diet twice daily at the time of 08:00 and 17:30 hours during the morning and afternoon following milking. Cows were hand milked twice daily between 04:00 and 06:00 hours in the morning and between 16:00 and 17:30 hours in the afternoon.

Treatments and Experimental Animals

A total of 16, two to four multiparious Holstein Friesian dairy cows at mid-lactation of 110.94 ± 18.9 days in milk, 10.5 ± 2.14 kg day^{-1} milk yield and 383.5 ± 35.44 kg average body weight were selected from the milking herd of the college's dairy farm. All the selected cows were weighted and medicated against internal parasite with Albendazol (2500mg $250kg^{-1}$ body weight of cows) and external parasites weekly with Diazinol (Amitraz 12.5% of 1.6ml/l of water), checked with California Mastitis Test (CMT) prior to the experiment. Finally, those selected and treated animals were randomly allotted to one of the four dietary treatments (Table 1) based on their average milk yield on a randomized complete block design (RCBD).

Table 1: Experimental treatments

Treatments	Experimental diet
T1	0 % Bole in the concentrate (Control)
T2	1.5 % Bole in the concentrate
T3	3 % Bole in the concentrate
T4	4.5% Bole in the concentrate

Data Collection and Sampling Procedure

Feed intake measurement

Feed offered and the corresponding refusals of grass hay and concentrate mix with bole were weighed and recorded daily to determine daily feed intake throughout the experiment.

Milk yield and milk composition

Daily milk yield for each cow was recorded using Salter suspended balance throughout the experiment. Thoroughly mixed (morning and afternoon) milk samples were taken using a glass measuring cylinder (100ml capacity) twice during the last week from each batch of experimental dairy cows. The collected sample milk was stored in the refrigerator at -20°C pending analysis. Finally, milk components of milk fat, protein, solids not fat and total solids were calculated for the last week of the experiment and 4% fat corrected milk yield (FCM) and Feed conversion efficiency (FCE) was calculated to standardize treatment comparisons following the NRC (1989) formula:

FCM (Kg/day) = 0.4 x MY (Kg/day) + 15 x FY (kg/day)

FCE = (Mean daily milk yield) / (Mean daily DM intake)

Where; MY= Milk Yield, FY= Fat yield

Chemical Analysis

Composition of feeds and soil

All samples of grass hay, concentrate and the mineral soil were analyzed for dry mater (DM), organic matter (OM), ash and N (Kjeldahl-N) using standard procedures of AOAC (1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using the Van Soest and Robertson (1985) method. The *in vitro* organic matter digestibility (IVOMD) was determined using the procedures of Tilley and Terry (1963). Metabolizable energy (ME) contents of the feeds were estimated from the percentage of *in vitro* organic matter digestibility (% IVOMD) x 0.16 as suggested by McDonald *et al.* (2002). Calcium (Ca), Na, K, Mg and Mn contents of the soil were analyzed according to Perkins (1982), using atomic absorption spectrophotometer and P was determined using auto analyzer according to AOAC (1990).

Milk composition

Milk composition was analyzed for fat, protein, solid not fat (SNF) and total solids (TS) percentage using Milko Scan (Ultra Milk analyzer, Milkana Kam 98-2A, Foss electric, Denmark) according to the manufacturer's instruction.

Statistical Analysis

Data on voluntary DM and nutrient intake, milk yield and milk composition were subjected to analysis of variance (ANOVA) procedure for RCBD using GLM procedure of SAS (2002). Differences between treatment means were separated using Least significance different (LSD). The model used to analyze the treatment effects on intake, milk yield and milk composition was:

$y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij}$

Where: y_{ij} = an observation in treatment i and block j

μ = the overall mean

τ_i = the effect of treatment i

β_j = the fixed effect of block j

ε_{ij} = random error

RESULTS AND DISCUSSION

Chemical Composition and *In-Vitro* Organic Matter Digestibility of Feeds

The chemical compositions and *in-vitro* organic matter digestibility of grass hay (GH) (offered and refusal) and concentrate supplement are presented in Table 2.

The feed classification of Lonsdale (1989), feed stuffs having >20, 20 to 12 and <12% protein content and >12.0, 12.0 to 9.0 and < 9.0 metabolizable energy content (MJ/kg DM) are high, medium and low, respectively. Based on this classification the concentrate and grass hay which were used to the present study, the concentrate diet was categorized under medium protein content and high metabolizable energy while grass hay lower in protein and medium metabolizable energy category. According to Singh and Oosting (1992), grass hay with NDF value of 69.90%, which was used in the present study can be categorized under poor quality feeds while the concentrate mix of NDF value 33.65% categorized under high quality feeds.

The lower crude protein and the higher fiber content of grass hay which was used in the present study may be related to that of the grass hay was harvested after the flowering stage (late cutting) and stayed for a long period of time on field after cutting. According to Adugna Tolera (2008), the grass or legumes which were harvested in the vegetative (immature) stage have relatively higher protein and digestible carbohydrate and lower fiber contents, late cutting of hay can also cause a loss of about 20% in digestibility of the forage.

Table 2: Chemical composition, *in-vitro* organic matter digestibility and estimated metabolizable energy of experimental feeds

Chemical composition	Grass hay		Concentrate mixture
	Offer	Refusal	
Dry matter (%)	92	90	90
Ash (% DM)	10.24	8.60	8.90
Crude protein (% DM)	4.73	2.85	17.98
NDF (% DM)	69.90	75.06	33.65
ADF (% DM)	54.30	63.04	19.60
Hemi-cellulose (% DM)	15.60	12.02	14.05
IVOMD (% DM)	63.15	60.16	78.18
EME (MJ Kg^{-1}DM)	10.10	9.63	12.51

NDF=neutral detergent fiber; ADF=acid detergent fiber; IVOMD= *in vitro* organic matter digestibility; EME=estimated metabolizable energy ME=0.16 (% IVOMD); Concentrate mixture= noug (*Guizotia abyssinica*) seed cake (33%), wheat bran (54%), crushed maize grain (10%), ground limestone (2%) and common salt (1%)

Mineral Composition of Bole Soil from Central Rift Valley Lakes

The chemical composition of Bole soil on different parts of Ethiopian lakes and experimental diet are presented in Table 3. Concentration of minerals in Bole soil from different Lakes reported on different years was different from the current result. The concentration of all minerals except phosphorus within bole soil used for the present study was lower than the report of Adugna Tolera (2008) on the same lake (Lake shala). This might be due to additional mixed of another type of soil, variations during mineral analysis, depth of soil sample taken and/or during sample taken from different body parts of lakes. The report of mineral concentration on Lake Abiyata, which was reported by Nega *et al.* (2006) except K, Na and Mn was lower than the present study. According to

Table 3: Mineral concentration of Bole soil and experimental diets

Bole soil reported by	Major and Trace minerals %					ppm	Lakes
	Ca	P	Mg	K	Na	Mn	
Nega *et al*., 2006	0.21	0.04	0.08	1.13	36.84	11	Abiyata
Adugna Tolera, 2008	1.70	0.02	1.50	0.73	10.3	47100	Shala
	0.35	0.02	0.02	0.59	3.5	63500	Zewaye
	3.41	0.03	0.47	0.78	5.41	451.6	Abaya
The present study pH=9.80	0.70	0.06	0.09	0.31	6.14	4.61	Shala

Table 4: Means of dry matter and nutrient intake of lactating Holstein cows fed on different levels of bole soil with hay and concentrate

Parameters	Treatments				SEM	SL
	T1	T2	T3	T4		
Grass hay, kg/d	8.36^b	9.32^a	7.96^b	8.18^b	0.23	**
Concentrate, kg/d	4.26	4.71	4.63	4.27	0.14	ns
Total DMI kg/d	12.62^b	14.03^a	12.59^b	12.46^b	0.53	*
Nutrient intake, kg/d						
Ash	1.23^b	1.37^a	1.23^b	1.22^b	0.005	*
CPI	1.16	1.29	1.21	1.15	0.006	Ns
NDFI	7.27^b	8.10^a	7.12^b	7.16^b	0.165	*
ADFI	5.37^b	5.99^a	5.23^b	5.28^b	0.09	*
Hemi cellulose	1.90^b	2.12^a	1.89^b	1.88^b	0.011	*
MEI (MJ/d)	13.77	15.31	13.83	13.62	0.66	Ns

Table 5: Means of daily milk yield, milk composition, and production efficiency of dairy cows fed hay and concentrate supplemented with deferent levels of bole soil

Parameters	Treatments				SEM	SL
	T1	T2	T3	T4		
Milk and component yield, kg/d						
Milk yield Kg/day	9.02	11.04	9.58	8.84	1.24	Ns
4% FCM	9.04^b	10.04^a	10.12^a	9.01^b	0.18	**
FCE(FCM/ TDMI)	0.72^b	0.72^b	0.80^a	0.73^b	0.001	*
Milk Composition, %						
Fat	3.62^b	3.75^b	4.19^a	3.65^b	0.07	*
Protein	3.25	3.25	3.25	3.27	0.034	Ns
SNF	7.73	7.73	7.76	7.79	0.17	Ns
TS	11.35	11.48	11.95	11.44	0.25	Ns

[a,b] means in the same row with different superscripts are (*)= significantly different at p<0.05; (**) = significant at p<0.01; SL = significance level; SEM = standard error of mean; ns = not significant T1= 0 % bole in the concentrate; T2= 1.5 % bole in the concentrate; T3= 3 % bole in the concentrate; T4= 4.5 % bole in the concentrate; 4 % FCM=fat corrected milk; SNF=solid not fat; TS = total solid; FCE (FCM/TDMI) = feed conversion efficiency (ratio of FCM to total DM intake); SNF = solid not fat; TS = total solid

(Soil Survey Division Staff, 1993) soil pH classification soils having >9.0 pH are categorized under very strongly alkaline. Based on this classification bole soil used to the present study was categorized under very strongly alkaline.

Dry Matter and Nutrients Intake

Means of dry matter and nutrient intake are presented in Table 4. Daily grass hay intake of animals in T1, T3 and T4 were lower than T2. Daily mean concentrate intake was not statistically different (P>0.05) among treatments. Average daily total dry matter intake (TDMI) and ash (kg/d) were significantly different (P<0.05) among treatments. Cow's fed on T2 (1.5% bole) had consumed higher (14.03 kg/d) dry matter than T1, T3 and T4. The difference in ash intake between treatments may be the level of bole intake increases, which affects and reduced the total dry matter intake. Dietary treatments did not affect crude protein (CP) intake (P>0.05) among treatments.

The intake of NDF and ADF were significantly (P<0.05) different among treatments. Intake of both NDF and ADF of T2 were significantly higher (P<0.05). The difference intake of both NDF and ADF among treatments may be due to the different intake of grass hay.

Daily intake of metabolizable energy (MEI) were not significantly different (P<0.05) between treatments. Compared to the daily requirement of metabolizable energy among treatments for lactating dairy cows calculated based on their average milk yield, fat and solid not fat yield for T1, T2, T3 and T4 were numerically different 24.77, 30.88, 28.47 and 24.63 MJ/d respectively. The ratio of forage to concentrate consumed of the present study were 66:34, 66:34, 63:37 and 66:34 for diets of T1, T2, T3 and T4 respectively.

Total dry matter intake of the present study was in line with the report of other authors conducted on mineral intake. According to the report of NRC (2001) dry matter intake respond over a range of dietary sodium concentrations (0.11 to 1.20 percent, dry basis) were curvilinear, with maximum performance at 0.70 to 0.80 percent sodium, dry basis. Therefore, on the report of the present study cows at T2 respond a better dry matter intake than the other treatments. Therefore, the difference in total DMI among diets on the present study might be related with the level of mineral intake of sodium. This is not only the reason for the difference on DMI, which might be also related with body size, amount of concentrate supplement, production level and specially level of bole soil intake.

Milk Yield and Milk Composition

Results of the effect of different levels of Bole soil on daily milk yield and milk composition of dairy cows are shown in Table 5. Daily milk yield were not significantly (P>0.05) different among treatments. However, 4% fat corrected milk (FCM) was calculated and significantly different (P<0.01) among treatments. Animals on T2 and T3 tended to have higher FCM than the other treatments; numerically T4 recorded lowered both actual milk yield and FCM than the controlled group. Treatment effects on milk component showed that, milk fat content were significantly (P<0.05) different between treatments. However, milk protein, solid not fat and total solid content were not significantly (P>0.05) different among treatments.

Supplemented of bole soil on feed conversion efficiency (FCE) were significantly (P<0.05) difference among treatments. Lactating cows on T3 were able to produce more milk (P<0.05) from the same amount of DM consumed as compared to the other treatments.

Results of the present study were agreed with Nega *et al.* (2006) the milk yield of lactating dairy cows was not significantly different by supplementing the natural mineral soil (Bole). Nega *et al*. (2006) also evaluated that animals fed a concentrate diet supplemented with cotton seed cake (CSC), bole or the combination of CSC and bole increased milk fat content by about 11.1%, 12.5% and 11.1% respectively, than the control diet. The author suggested for the increment of milk fat content was probably bole soil might have a buffering effect on the rumen environment, which resulted in the decreased ruminal propionic acid production and increase the ratio of acetic acid to propionic acid in favor of milk fat yield (Rogers *et al.,* 1982).

According to the report of MacDonald *et al*. (2002), changes in fat content are erratic but crude protein shows little change. Inclusion of the same level of 3% bole with concentrate on the effect of milk fat and total solid to the present study 15.75 and 5.29%, respectively was higher 11.14 and 4% respectively than the report of Nega *et al*. (2006) as compared to the control group. The difference report might be due to the difference in metabolizable energy intake and intrinsic factors like level of production, parity, stage of lactation, external factors like environmental stress, unequal intervals between milking and changes in feeding.

Conclusion and recommendations

The overall results of the present study revealed that cheap and locally available Bole (Lake) soil is one of the mineral containing soils, which predominantly contains essential minerals of Ca, P, Mg, K, Na and Mn. Supplementing bole soil with concentrate at 1.5% improves the cow's total dry matter intake. The soil supplementation affected the milk fat content of the dairy cow without affecting milk protein, solid not fat and total solid contents. However, milk yield is negatively affected when the soil level supplement is increased, especially cows at 4.5% of the soil produced lower milk than the non supplemented animals. Generally, supplementing 1.5% of bole soil with concentrate diet is one of the strategies to improve dry mater intake and milk composition of Holstein Friesian cows, and used as a mineral supplement for lactating dairy cows. Based on this information, it is recommended that the government should give due attention for bole soil as a mineral supplement for dairy development improvement strategy and further researches on buffering capacity of bole soil on rumen environment, replacement ability of bole soil by commercial minerals and intake of bole soil on milk mineral composition should be conducted.

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