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Effects of Lake Soil and Cottonseed Cake Supplementation on Milk Production and Postpartum Reproductive Efficiencies of Lactating Cows

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ABSTRACT

A study was conducted to investigate the effects of lake soil (bole) and cotton seed cake supplementation on milk production and postpartum reproductive efficiencies of lactating Holstein-Frisian dairy cows fed a basal diet of native grass hay and a concentrate diet with/without cottonseed cake and/or lake soil (bole). Thirty two pregnant animals with 524±54 kg average body weight were blocked by their due date of calving as early or late. Soon after calving each animal was assigned in a randomized block design to one of the four dietary treatments of concentrate alone (control), Concentrate + 45%Cottonseed cake, Concentrate + 3%lake soil (bole), and Concentrate + 45%cottonseed cake + 3%lake soil. Significant ($p<0.05$) treatment effect was observed on hay dry matter intake. Highest intake was observed in animals supplemented with concentrate + CSC + lake soil followed by those supplemented with concentrate + lake soil. The intakes of the supplements, total dry matter, crude protein and metabolizable energy were not significantly ($p>0.05$) affected by treatments. Similarly, there was no significant ($p>0.05$) treatment effect on actual and 4% fat corrected daily milk yield as well as kg milk yield per kg of dry matter intake. However, animals under treatment diets of concentrate + CSC, concentrate + lake soil and concentrate + CSC + lake soil produced 7.4, 16.3 and 18.2% higher actual daily milk and 14.3, 24.2 and 25.7% higher fat corrected daily milk yield than the control group. Although the days from calving to estrus, days open and the number services per conception were not significantly ($p>0.05$) differed among treatments, shorter days from calving to estrus, days open and less number of services per conception was observed in animals supplemented with concentrate and 3% lake soil alone than the other treatment groups. The efficiencies of milk yield per kg supplement and the cost of supplement per kg milk produced was significantly ($p<0.05$) different among treatment groups. Thus supplanting a concentrate diet with 3% lake soil alone was found biologically and economically profitable.

Abbreviations: *AOAC,* Association of official analytical chemists; *C, concentrate; CP, crude protein; CSC, cottonseed cake; DM, dry matter;* DMI, dry matter intake; *EE, ether extract;* GLM, general linear model; IVOMD, invitro organic matter digestibility; ME, metabolizable energy; MJ, mega joules; *NDF, neutral detergent fiber; NRC, national research council; NSC, nonstructural carbohydrate; OM, organic matter;* SAS, statistical analysis system;

KEY WORDS: *milk yield, lake soil, cow, reproduction, efficiency, Ethiopia*

INTRODUCTION

In Ethiopia, small and large scale dairy farms in the urban and peri-urban centers provide most of the milk volume channeled to cities and towns where demand for milk and milk products is high [3]. These farms are characterized with different levels of management, inadequate and unbalanced feed supply resulting in low total milk output reduced milk yield per cow and reduced replacement stock [29; 1]. Feeds rich in energy, protein and minerals (mainly calcium and phosphorus) are important for optimum milk production and reproductive efficiency of dairy cows. Most dairy farmers around the urban and peri-urban centers heavily rely on mill by-products than mixed and balanced concentrate.

The mix of available concentrate feeds also largely depends on available materials and quantity, than quality of nutrients required. The most commonly used feed resources for dairy animals are natural grass and legume hay, wheat bran and middling, and niger seed (*Guizota abyssinica*) cake [29]. In addition, cottonseed cake is one of the available oil seed cakes widely used in fattening operation. Although, cottonseed cake is considered as a rumen bypass protein source, it is rarely utilized in commercial farming system in Ethiopia, and information on its potential in productive and reproductive performances of dairy cattle is limited.

Levels of essential minerals in most commonly used fibrous feed resources in Ethiopia was studied and reported to be deficient [10]. [28] also reported that locally produced oilseed cakes were low in calcium and sodium contents. The existing animal feeds processing firms include limestone and common salt in concentrate mixtures as mineral sources based on availability. A salty lake soil locally known as "bole" is abundantly and cheaply available in the central rift-valley lake of Abiyata and used by local farmers as a mineral supplement for their

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cattle. However, documented information on the nutritive value and effect of" bole" (lake soil) on milk production and postpartum reproductive efficiency of lactating dairy cows is limited.

Therefore, this study was aimed to evaluate the effects of supplementing cottonseed cake and lake soil on milk production and postpartum reproductive efficiencies of lactating dairy cows in Ethiopia.

MATERIALS AND METHODS

Study area

This study was conducted at Holeta Dairy Farm belonging to cattle genetic improvement center of Federal Ministry of Agriculture. The farm is located at about 44 km to the West of Addis Ababa, at 9°3'N latitude and 38°30'E longitude. It has an altitude of 2390 meters above sea level and receives an average annual rainfall of about 1700-mm. The rainfall is erratic and bimodal with the main rains occurring from June to September. The minimum and maximum average temperature is 6.3°C and 22.1°C respectively.

Experimental animals and management

Thirty-two pregnant Holstein Friesian cows with average body weight of 524±54kg were blocked by their expected due date of calving as early (B1) and late (B2). Soon after calving animals were assigned in a randomized complete block design to one of the four dietary treatments of concentrate alone (control), 45% of the concentrate diet by weight substituted with cottonseed cake (C+CSC), concentrate plus 3% bole (lake soil) (C + Bole) and 45% of the concentrate replaced with cottonseed cake plus 3% bole (C + CSC + Bole). Data on milk yield, feed intake and refusals were collected on daily basis starting from day one postpartum for 135 days. The level of lake soil was limited to 3% due to limitation of experimental animals and economical reason to use different levels. The compositions of the commercially formulated concentrate (control) diet was wheat bran (55%), wheat middling (10%), nougseed (*Guizota abyssinica*) cake (30%), limestone (3%) and common salt (2%). The CSC used in this trial was from mechanical oil extracting factory. Animals were individually penned and fed with *ad libitum* native grass hay.

The experimental diets were offered at the rate of 0.5kg per kg of milk yield in two equal feedings before the morning and evening milking. Water was offered three times daily in the morning, noon and evening. Animals were hand milked twice daily at 6 to 7 AM and 4 to 5 PM and daily milk yield was recorded accordingly. Feed samples were collected weekly, bulked, sub-sampled and delivered to laboratory for chemical analysis. Milk samples from individual animal were collected twice during the last week of the experiment (week 18 postpartum) and delivered to laboratory for milk fat, protein and total solid analysis. Sign of estrus manifestation was detected by visual observation three times daily, early in the morning, noon and evening. Costs of supplemental feeds per kg of milk yield for each treatment groups was estimated based on the market prices of the mixed concentrate, cottonseed cake and bole soil. The concentration of non structural carbohydrate (NSC) in each dietary treatment was estimated as, NSC = 100 – (%CP + %NDF + %EE + %Ash) according to [19].

Chemical analysis

The dry matters (DM), organic matter (OM) and nitrogen content of the feeds were analyzed using standard procedures 7.003, 7.009 and 2.057 of [2]. Neutral detergent fiber (NDF) was determined using the method described by [33]. The NDF was assayed without alpha amylase or sodium sulfite, and expressed on an ash free basis. The *in vitro* organic matter digestibility (IVOMD) was determined using the procedures advanced by [31]. Metabolizable energy contents of the feeds was estimated from *in vitro* organic matter digestibility (IVOMD (g/kg DM) x 0.016) as suggested by [13] and [4]. Calcium (Ca), sodium (Na), potassium (K), magnesium (Mg) and manganese (Mn) contents of the feeds were analyzed using atomic absorption spectrophotometers and phosphorus (P) content was determined using auto-analyzer according to [2]. The intake of nutrients was estimated by multiplying the total DM intake of the various feeds with their respective nutrient concentration per kg dry matter using [11 and 17].

Statistical analysis

Data were analyzed using general linear model (GLM) procedure of [30]. Differences between treatment groups on intake of feeds and nutrients, milk production and reproductive efficiencies were evaluated using Duncan multiple range test. The model used to analyze the treatment effects on feeds and nutrient intake, milk production and reproductive efficiencies was:

$Y = \mu + b_i + t_j + e_{ij}$

Where, Y = means for response variables

μ = overall mean

b = effects of i^{th} block of calving time (b = 1, 2)

t = effects of j^{th} treatment of concentrate supplements (t = 1, 2 …4)

e = error term

RESULTS

Chemical compositions of experimental feeds

Chemical compositions of the grass hay and the experimental diets are presented in Table 1. In the grass hay, low concentrations of CP, EE, Ash and IVOMD were observed, while the concentration of NDF was higher. Although it was slightly higher than the critical level suggested by [14] the level of Ca was marginal, while that of P, Na and Mg were below critical level. All treatment groups were sufficiently high in CP, NDF, EE and IVOMD concentrations.

Calcium, P, Na, K, Mg and Mn contents of all the concentrate mixtures were sufficiently higher than the recommended levels of 2.5 to 4.8, 0.6 to 2.5, 8.0 to 12.0, 1.9 to 3.0 (dry matter basis) and 40 to 100 mg/kg DM respectively [14]. The ratio of Ca to P in the control diet (C) and C + bole were sufficiently high, but in the other two treatments where CSC was included it was below critical levels suggested by McDowell [14]. Sodium contents of C+ bole and C+ CSC + bole treatments were higher than the treatment diets of C and C+ CSC. All treatment diets were almost similar in the contents of P, K and Mg.

Table 1 Mean chemical compositions of the experimental diets for cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Experimental diets	g/kg DM)												(mg/kg)	Ca: P[c] ratio
	DM	CP	OM	NDF	EE	Ash	IVOMD	Ca	P	Na	K	Mg	Mn	
Hay	910	49	920	720	117	83	463	4	1.7	0.2	14.8	1.7	340	2.4:1
C (control)	890	201	890	390	507	110	669	11.7	8.8	4.8	10.9	4.1	147	1.3:1
C + CSC[a]	900	219	920	460	618	85	625	7.4	8.2	3.9	12.2	3.8	82	0.9:1
C + bole[b]	900	202	840	320	431	159	665	11.2	8.3	13.9	10.3	3.9	151	1.4:1
C+CSC + bole	910	219	880	470	570	118	630	7.9	7.7	8.8	11.6	3.8	98	1:1
CSC alone	950	249	940	480	78	56	557	2.1	8.6	0.2	13.3	3.5	8.8	0.24:1
Bole (lake soil)	-	-		-	-	-	-	2.1	0.4	368.4	11.3	0.8	11	5.3:1
Critical levels of minerals [c]	-	-	-	-	-	-	-	3.0	2.5	0.6	6.0-8.0	2.0	30-40	1.2:1

[a] CSC=cotton seed cake; C=concentrate.
[b] Bole = a salty lake soil used by local farmers as a mineral source.
[c] *Adapted from McDowell (1997).*

Feeds and nutrients intake

Means of feeds and nutrient intake of lactating cows fed hay and concentrate supplement with/without cottonseed cake and/or bole is presented in Table 2. Daily intakes of hay was significantly ($P<0.05$) different among treatments. There was 3.42, 10.43 and 13% higher intake of hay for animals supplemented the treatment diet of C + CSC, C + bole and C +CSC + bole respectively than the control group. The intakes of supplement, total DM, CP and ME were not significantly ($P>0.05$) different among treatments. However, there were relatively higher intakes of supplement, total DM, CP and ME was observed in C + bole and C + CSC + bole treatment group. Daily CP intake of animals under treatments C, C + CSC, C + bole and C + CSC + bole were 13.4, 20.6, 4.06 and 4.31% higher respectively than the estimated daily requirements. The intake of those under treatment C + bole and C + CSC + bole were nearly at requirement level. Daily intake of ME (MJ/day) for animals in treatments C, C + CSC, C + bole and C + CSC + bole were 4.4, 10.3, 9.6 and 13% lower respectively than the estimated daily requirement (Table 2).

Significant differences were also observed in the dietary intakes of NDF ($P<0.01$), EE and NSC ($P<0.001$) among treatments (Table 2). Relatively higher intakes of NDF and EE (%DMI) were observed by animals fed a concentrate diets substituted with CSC, while the intake of NSC was depressed with these two dietary treatments than the other two counterparts. The intakes of NSC (%DM) in all the dietary treatment groups were below the recommended range of 30 to 46% reported by [20]. The lower NSC concentration throughout the dietary treatments may be attributed to excessive wheat bran and middling (65%) and lower grain contents of the diets [25].

Table 2 Means of feeds and nutrient intake of lactating cows fed hay and a concentrate supplement with/without cottonseed cake and/or bole.

Parameters	Treatments [d]				SE	P
	C	C+ CSC	C+ bole	C+CSC+ bole		
Hay intake (kg/d)	5.85^{c}	6.05^{bc}	6.46^{ab}	6.61^{a}	0.18	*
Supplement intake (kg/d)	8.25	8.60	8.84	9.07	0.55	NS
Total DM intake (kg/d)	14.10	14.65	15.30	15.68	0.62	NS
CP intake (g/day)	1,944	2,179	2,103	2,300	188.51	NS
CP Requirement (g/day)x	1,715	1,807	2,021	2,205	117.90	
CP (% DMI)	13.67^{b}	14.75^{a}	13.70^{b}	14.58^{a}	0.27	**
ME intake (MJ/day)	132	131	142	140	6.16	NS
ME Requirement (MJ/d)	138	146	157	161	7.60	
ME (MJ/Kg DM)	9.3	8.9	9.3	8.9	0.05	NS
NDF (%DMI)	53^{b}	57^{ab}	49^{c}	58^{a}	0.52	**
EE (%DMI)	3.4^{c}	4.05^{a}	2.90^{d}	3.8^{b}	0.08	***
NSC (%DMI)	20.3^{a}	15.9^{b}	22.3^{a}	14.5^{b}	0.93	***

[d] C= concentrate; CSC = Cottonseed cake; NSC=nonstructural carbohydrate
[x, y] CP and ME requirements were estimated based on average body weights and actual milk yields of individual animal in each treatment group.
* = $P<0.05$; ** = $P<0.01$; *** = $P<0.001$; NS=not significant.
[a, b,] means with the different superscripts in the same row are significantly different ($P<0.05$).

Milk production and reproductive efficiency

Daily actual milk yield, FC milk yield, and milk production efficiency of cows fed hay and a concentrate supplement with/without cottonseed cake and/or bole is presented in Table 3. Daily actual milk yield and FC milk yield were not significantly (P>0.05) different among treatments. However, higher yield of both were recorded by animals supplemented a concentrate diet with either CSC alone, or bole alone or the combination of CSC and bole than those fed the control diet. Animals fed dietary treatments of C+CSC, C + bole and C+ CSC + bole produced 7.4, 16.3 and 18.2% higher actual milk respectively and 14.3, 24.2 and 25.7% higher 4% fat corrected milk respectively than those fed the control diet.

In this study inclusion of bole soil in a concentrate diet alone or in combination with CSC supported 8.2 and 10% higher daily actual milk yield and 8.6 and 10% higher FC milk production respectively than feeding a concentrate diet with CSC alone.

Daily milk yield per kg DM intake was not significantly (P>0.05) different among treatments. However, relatively higher milk yield per kg DM intake was observed for animals supplemented with bole alone. There was significant (P<0.05) treatment effect on daily milk yield per kg supplement. Animals fed a concentrate supplement with bole alone or with the combination of bole and cottonseed cake produced similar and higher daily milk than the other treatment groups. There was also significant (P<0.05) treatment effect in costs of supplement per kg daily milk yield (Table 3). A lower cost of supplement per kg milk for animals fed concentrate diet with bole alone followed by the group supplemented the combination of CSC and bole was observed. The costs of feeding either concentrate alone, or supplemented with CSC and/or bole were not significantly (P>0.05) differed. Inclusion of bole alone can reduce the cost of milk production through increased productivity. Feeding a concentrate diet with 3% bole alone was 18.4, 14.3 and 12.2% more profitable than feeding the control, control plus cottonseed cake and control plus cottonseed cake plus bole respectively.

Statistically no significant (P>0.05) effects of treatments were observed on all the reproductive parameters measured. However, there were shorter days from calving to first estrus (71), days open (86) and lower number of services per conception (1.4) for animals supplemented a concentrate diet with bole alone compared to those animals fed the control diet (79.6 days, 101.9 days and 1.6), the C+ CSC (88.6 days, 148.2 days and 2.0), and the C + CSC + bole (73 days, 114 days and 1.9) respectively.

DISCUSSION

In grass hay, the low concentrations of CP, EE, Ash and IVOMD observed and the high NDF content were as expected from poor quality hay, may be attributed to harvesting management. In the dietary concentrate mixture of the treatments with 45% CSC (C+ CSC and C+CSC+ bole), the relatively higher concentrations of CP, OM, NDF and EE may be due to the substitution of concentrate diet with 45% cottonseed cake in the two dietary treatments. However, the crude protein content of CSC used in this study was lower than the expected value of over 36%, and it was similar to the value for whole cottonseed reported elsewhere [18; 27. This low crude protein content may be attributed to either mechanical method used for oil extraction or due to high hull content of the CSC as a result of .poor processing during de-hulling. Although, the hulls have their own nutritional significance in providing fiber to the recommended level, the impurities of cottonseed from hulls may depress the proportion of crude protein content. [26and 24] observed similar results that cottonseed hulls have negative effect on crude protein content of the feed.

The low concentration of the essential minerals measured (Ca, P, Na and Mg) in grass hay was consistent with the report of [9] probably resulting from factors such as soil, plant species, stage of maturity and climate [8; 14]. The levels of K and Mn were sufficiently high for ruminant. Relative to the critical level recommended by [14], the levels of mineral elements considered in this study were sufficiently high. However, since Ca content of cottonseed cake was lower (0.21 %DM) its inclusion in the treatment diets of C+ CSC and C+ CSC+ bole depressed Ca contents of these diets and similar trend was observed in the ratio of Ca to P. The higher Na concentration in the treatments C+ bole and C+ CSC + bole than the other two counterparts may be due to the inclusion of bole (lake soil) which had higher concentration of Na.

The higher daily intake of grass hay (kg DM) by animals under treatments C + bole and C + CSC + bole may be due to the higher supply of Na and Mn in these treatments relative to the others, since the presence of salt in the feed can contribute to its palatability [32]. The relatively higher intakes of supplement, total DM, CP and ME in these treatment groups may be also attributed to the concentration of these minerals.

The statistically none significant difference in actual and fat corrected milk production and postpartum reproductive efficiencies among treatments may be due to individual variability of animals within the group. The relatively higher milk productivity and milk production efficiencies in terms of kg milk per kg supplement, kg milk per kg dry matter intake and supplement cost (Birr) per kg milk, and days from calving to estrus and days open of animals fed the concentrate diet C + bole and C + CSC + bole can be associated with the relatively higher intakes of corresponding hay dry matter, supplement, total dry matter, CP and ME. This explains that, productivity of ruminants is influenced primarily by feed intake, which in turn is determined by the digestibility and capacity of the diet to supply the correct balance of nutrients required [21]. In addition these differences may be attributed to sufficiently higher concentration of Na in these two treatments relative to the others. [23 and 5] reported that dry matter intake and milk yield was improved by dietary concentration of Na above those needed to meet requirements. Furthermore, as soils are usually considered to influence indirectly animal nutrition through the quantity and quality of herbage they produce, and there is also direct soil-animal effect [15]. Ingested soil provides a source of essential elements, and improves the utilization of energy and increases the availability of certain minerals [16]. Inclusion of soil in the diet of ruminants reduced fecal losses of Ca and Mg and increased apparent availability of both. It was also suggested by [16] that there may be some physiochemical processes induced by soil itself, since the increased apparent absorption and retention of Ca and Mg could not be attributed directly to the contents of these elements in the soil. The relatively longer days open in animals fed two dietary treatments with 45 % cottonseed cake may be due to excessive intake of dietary crude protein and lower intake of metabolizable energy than the estimated requirement. [11] reported that cows fed excess total protein produced more milk and showed signs of standing estrus earlier after calving as compared to groups of cows received lower CP. In addition, net energy balance occurring early during lactation delays the timing of first ovulation and exerts other carryover consequences on fertility during the breeding period. These effects include reduced or sub-optimum levels of progesterone in blood that influence fertility through alteration of uterine function and in adequate rate of early embryo development. Net energy balance may also detrimentally impact the oocyte that is released after ovulation [6;7].

However, they tended to have lower conception rate and consequently were open longer and required more services per conception. In addition, the relatively higher concentration of Na (13.9 g/kgDM) and Mn (151 mg/kgDM) may also resulted in shorter days from calving to first estrus, days open and lower number of services per conception for animals supplemented a concentrate diet with bole soil alone as compared to the other counter parts. The longer days from calving to first observed estrus, days open and higher number of services per conception for animals fed a C + CSC may also be due partly to marginal concentrations of calcium, sodium and magnesium as well as lower ratio of calcium to phosphorus in this dietary treatment because, mineral supply is strongly associated with reproductive performances of dairy cows [12]. Feeding calcium deficient diet may delay uterine involution, and fertility can be impaired by feeding diet with calcium to phosphorus ratio of less than 1.5 or greater than 3.5 [25]. Although, dietary phosphorus concentration was more adequate than needed to meet the requirements throughout the treatments, it could not equally improved reproductive efficiencies of animals in treatments, C + CSC and C + CSC + bole, as those fed the concentrate (control) or C + bole diets, may be due to marginal level of calcium concentration in these treatment and the interaction of the two mineral elements. [25] reported that high phosphorus intakes along with low calcium intakes depressed fertility in dairy cows. This indicates the need for synchronizing and balancing dietary concentrations of the two mineral elements. The relatively higher dietary concentration of potassium than needed to meet requirements in treatments with CSC alone or its combination with bole may be also one of the possible contributing factors for the relatively lower reproductive performances of animals under these treatments than the other treatment groups. [12] reported that feeding high level of potassium delayed ovulation in dairy cattle. Even though the concentration of manganese was sufficiently higher than the requirement level throughout the treatment groups the levels in the dietary treatments with C + CSC and C + CSC + bole was depressed and can be associated with the relatively lower reproductive efficiencies of animals under these treatments. Manganese is one of the trace minerals associated with ovarian function. Cows fed on low manganese diets were slower to exhibit estrus, more likely to have silent heat and lower conception rate than cows fed sufficient manganese in their diets [22].

The low reproductive efficiencies of animals fed the two dietary treatments of C + CSC and C + CSC + bole can be also related to the relatively lower concentrations of NSC (15.9 and 14.5% respectively) than the other two dietary treatments (20.3 and 22.3% respectively). Due to low concentration of NSC, energy supply can be low and the functioning of normal estrous cycle after calving depends on the energy balance of the animals [12].

Although supplementing a concentrate diet with CSC alone or in combination with bole improved daily actual milk yield, and FC milk yield, there was longer days from calving to first observed estrus, longer days open and higher number of services per conception. Inclusion of 3% bole alone improved the actual and 4% fat corrected milk, milk production efficiency, the reproductive parameters measured and was also economically profitable.

Conclusion and Recommendations

Although statistically none significant, substituting a concentrate diet with 45% cottonseed cake improved both actual and fat corrected milk yield, but it was biologically and economically less attractive than including 3% bole alone. Supplementing a concentrate diet with 3% bole alone was found biologically and economically profitable. Inclusion 3% bole soil alone improved milk production and postpartum reproductive efficiency of lactating cows. Different levels of both CSC and lake soil at which optimum efficiency can be obtained needs further investigation.

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