THESIS

PRODUCTIVE AND REPRODUCTIVE RESPONSES OF LACTATING DAIRY COWS TO DIFFERENT FEEDING MANAGEMENTS IN OROMIA, ETHIOPIA

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A Thesis Submitted in Partial Fulfillment of
the Requirement for the Degree of
Doctor of Philosophy (Tropical Agriculture)
Graduate School, Kasetsart University
2006

ISBN 974-16-1902-2

Nega Tolla Koni 2006: Productive and Reproductive Responses of Lactating Dairy Cows to Different Feeding Managements in Oromia, Ethiopia. Doctor of Philosophy (Tropical Agriculture), Major Field: Tropical Agriculture, Interdisciplinary Graduate Program. Thesis Advisor: Associate Professor Pravee Vijchulata, PhD. 129 pages.
ISBN 974-16-1902-2

Two experiments were conducted with the overall objective to evaluate the influences of available feed resources and feeding managements on productive and reproductive responses of Holstein Friesian dairy cattle. The first trial was to study comparative performances of Holstein Friesian cows under smallholder and large scale farmers' management in central Rift Valley of Oromia, Ethiopia. This study was conducted in Central Rift Valley of Oromia at Arsi Negelle, Ziway, Adama and Lume districts of Eastern Shoa Zone. Three large scale peri-urban farms having 170 to 195 and 21 small scale urban farms having 1 to 10 heads of dairy animals were identified during the initial exploratory survey. Based on the willingness of the farm owners, the presence of dairy cows of graded Holstein Friesian genotype, known parity and stage of pregnancy two large scale farms and 12 small scale farms were randomly selected. A total of 28 animals from both large scale (14 animals average ± std body weight 427±42 kg) and small scale (14 animals average ± std. body weight 363±16 kg) were used for 28 weeks of data collection. The animals were within the parity ranging from 1 to 6. Significantly ($p<0.001$) higher milk yield was recorded on large scale farms than on the small scale farms. Milk components and reproductive parameters measured were not statistically differed between farm scales. Milk yield, milk components and reproductive parameters were not significantly ($p>0.05$) differed between parity classes. Although, the estimated amounts of crude protein and metabolizable energy consumed by animals were above requirements for the observed milk out put, the productivity of animals in both farm scales were below their genetic potential particularly that of small scale farms were critically low. The quality of dietary nutrients in terms of the proportion of rumen degradable to undegradable protein sources and structural and non structural carbohydrate needs further assessment for both farm scales. The second experiment was conducted at Holeta Cattle Genetic Improvement Center located 44 km to the West of Addis Ababa, to evaluate the productive and reproductive responses of lactating cows fed hay and concentrate supplement with/without cottonseed cake and/or bole. Thirty two Holstein Friesian cows with average±std body weight of 524±54 kg were blocked by their expected due date of calving. Soon after calving animals were assigned in a randomized complete block design to four dietary treatments of either commercially formulated concentrate diet, substituting 45% of the concentrate with cottonseed cake, concentrate plus 3% bole or substituting 45% of the concentrate with cottonseed cake plus 3% bole soil for 135 days. Substituting a concentrate diet with 45% cottonseed cake improved both actual and 4% fat corrected milk yield as well as milk fat content and yield. However, milk protein content, protein yield and protein production efficiency were lower than expected. This was due to low dietary energy supply resulted from lower concentration of nonstructural carbohydrate throughout the experimental diets. Nevertheless, including 3% bole alone in concentrate diet was biologically and economically more attractive than using either concentrates alone, concentrate plus cottonseed cake, or concentrate plus 45% cottonseed with 3% bole. However, optimum levels of cottonseed cake and bole at which maximum responses can be obtained need further investigation.

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ACKNOWLEDGEMENTS

First of all I thank The Almighty God for His unfailing love and help in all my life. My sincere thank goes to my academic advisor Associate Professor Pravee Vijchulata for his intellectual guidance and constructive criticisms from the onset of the proposal up to the final write-up of this Thesis. I also thank Associate Professors Pornsri Charatanayuth for her un-tired critical review and constructive comments as well as motherly hospitality. My sincere thanks also go to Associate professor Suwapong Swasdiphanich for reviewing, constructive criticisms and comments on this manuscript. I thank Mr. Tesfaye Cherinet and Mr. Tesfaye Hailu for their kindly permission of access to the experimental animals at Holeta station. Oromia Agricultural Research Institute and Ethiopian Agricultural Research Organization are highly acknowledged for funding this study. I express my gratitude to Dr. Skorn Koonawootrittriron for his valuable advice on the design of the experiment

I extend my thanks to my uncle Mr. Banjaw Korssa Guma without whose support my education was hardly possible and who further encouraged me to attain this status. My heart felt thank is to my wife Buruktawite Tekle who passed pain full and lonely hard time in shouldering responsibilities of looking after our children during my stay abroad, and her moral encouragement and care during my data collection had great contribution for my success. I thank my sister in law Azeb Tekele whose prayer and moral encouragement was regularly with me throughout my study period. The diligence and success of my elder son Samuel Nega in his academic career refreshed and encouraged my spirit of work during the final year of my study. I also extend my thanks to my daughters Bethlehem Nega and Eyerusalem Nega, and my son Nafyaad Nega for their long time tolerance of loneliness while I was away for this study. I am grateful to my cousin Ayantu Banjaw for her encouragement. The assistance and encouragement of Mr. Lidjalem Ofga'aa during my trip for study and the moral support of Dr. Worku Burayu is highly appreciated.

Nega Tolla Koni

May 2006

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LIST OF ABREVIATIONS

ADF = Acid detergent fiber

AI = Artificial Insemination

AOAC = Association of Organic Agricultural Chemists

CGM = Corn gluten meal

CP = Crude protein

CRV = Central rift valley

CSC = Cottonseed cake

DMI = Dry matter intake

DO = Days open

EAA= Essential amino acid

EE = Ether extract

FAO = Food and Agricultural Organization of the United Nation

FCM = Fat corrected milk

FMD = Foot and Mouth Disease

GDP = Gross Domestic product

HPT = High protein treated

HPU = High protein untreated

INVOMD = *in vitro* organic matter digestibility

LPU = Low protein untreated

ME = Metabolizable energy

MJ = Mega joule

NDF = Neutral detergent fiber

NRC = National Research Council

NSC = Nonstructural carbohydrate

OM = Organic matter

RDP = Rumen degradable protein

SAS = Statistical analysis system

SBM = Soybean meal

SCM = solid corrected milk

SPC = Services per conception

SPSS = Statistical Program for Social Science

TDN = Total digestible nutrient

TSBM = Treated soy bean meal

PRODUCTIVE AND REPRODUCTIVE RESPONSES OF LACTATING DAIRY COWS TO DIFFERENT FEEDING MANAGEMENT IN OROMIA, ETHIOPIA

INTRODUCTION

Agricultural sector has a significant place in Ethiopia's economy. Ethiopia is endowed with huge livestock population. Estimates of CSA (2004) suggest that Ethiopia possesses about 40.9 million heads of cattle, 25.5 million heads of sheep, 23.5 million heads of goats, 5.8 million heads of equines and 2.3 million heads of camels. The livestock sector contributed about 18 percent to the total gross Domestic Product (GDP), 40 percent to the agricultural GDP and 19 percent to the export earning (Winrock International, 1992). Livestock supply farm families with milk, meat, draught power, manure and serve as an immediate source of cash income. Milk is the first and an almost complete food for the growth and life of newborn as well as for adults. It is essential for normal physical and mental development of children. According to CSA (2003) in the year 2002 about 2,591,187 tones of cattle milk was produced Ethiopia, and 96 percent of this was produced from traditional rural holdings.

In Ethiopia, market oriented urban and peri-urban dairy farms are emerging as important component of milk production systems (Azage and Alemu, 1998). These systems are contributing immensely to fill the large gap between demand and supply of milk and milk products in urban centers. The systems involve the production, processing and marketing of milk and milk products that are channeled to consumers in the urban centers (Staal and Shapiro, 1996). Crossbred and graded animals are used by most of the farmers in these production systems.

Although the contribution of livestock farming is vital, its productivity in Ethiopia is generally very low due to lack of fair policy attention in terms of land ownership, dairy policy, price policy, import regulation, marketing system, infrastructure, information system, credit facilities, incentives, environmental issues and quality control (Azage and Alemu, 1998). Lack of participatory research, education and farmers training, extensions and consultation and dairy cooperatives are the major institutional constraints for the development of the sub-sector (Abaye *et al.*, 1991). Underdeveloped and lack of animal genetic resources, feed resources and feed markets, nutrition and feeding systems, animal health and disease control, management skill and processing and preservation of products are the major technical constraints of dairy development in the country (Abaye *et al.,* 1991; EARO, 1998). Due to these multifaceted constraints, the country could not be self-sufficient in milk and milk products and a considerable amount of foreign exchange have to be spent on the import of dairy products. In Ethiopia, an average per capita consumption of whole milk is far below that of the world and even than that of Sub-Saharan Africa (Table 1). Annual production of milk could not cope with the rapidly growing human population and the demand-supply gap has to be bridged with net import (FAO, 2004). The import of milk was increased from 2,082 metric tones in the year 1995 to about 11, 202 metric tones in the year 2002 (Table 2). Currently the human population of Ethiopia is estimated at about 72 million (FAO, 2004) and with annual growth rate of about 3% this figure will increase to about 110 million in the year 2020. Similarly urban population is expected to increase from the current 11 million to about 16.5 million by the year 2020. Population growth and urbanization are partly expected to add more stress on demands for dairy products.

This signifies the importance of dairy farming as a means of meeting human nutritional needs and improving farmers' income and living standards. Thus, its deficit imposes adverse effect on the economic and social development of the country. A practical strategy of improving the productive and reproductive potentials of dairy cattle depends on the supplementation of protein sources to optimize both the fermentative digestion in the rumen and the efficiency of utilization of the absorbed nutrients (Leng, 1999). Supplementing a diet with protein, energy and mineral source can increase the intake of poor quality roughage and as a consequence improves feed intake, body condition, milk yield and compositions, and reproductive efficiency of dairy cattle.

Table 1 Comparative per capita consumption of whole milk in Ethiopia and others (kg/year).

Year	Ethiopia	Sub-Saharan Africa	Whole Africa	World
1995	11.10	23.00	24.60	44.50
1996	12.40	22.20	24.10	46.00
1997	12.10	22.50	25.00	45.60
1998	11.80	22.60	25.10	45.80
1999	11.60	22.80	25.20	45.90
2000	14.80	23.90	26.20	45.70
2001	16.30	23.80	26.60	44.30
2002	15.90	24.20	26.70	44.20

Source: FAO (2004).

Table 2 Trends of annual human population, whole milk production, import and domestic supply in Ethiopia.

Year	Human population (000)	Production (Mt)	Import (Mt)	Consumption (Mt)
1995	57,349	889,100	2,082	891,182
1996	59,020	996,025	4,690	1,000,715
1997	60,607	1,007,420	4,690	1,012,110
1998	62,299	1,019,045	2,663	1,021,708
1999	63,936	1,030,435	1,838	1,032,273
2000	65,590	1,365,524	5,434	1,370,958
2001	67,266	1,518,107	3,202	1,521,309
2002	68,961	1,518,125	11,202	1,529,327

Source: FAO (2004).

Conserved native grass hay (mainly composed of *Digitaria decombens, Eragirostis pilosa, Trifolium repens and Trifolium prantense*), agro-industrial by-products and commercially formulated concentrate rations are the major feed resources used (Azage and Alemu, 1998) in the urban and peri-urban dairy production systems. However, there is no practice and skill of using nutritionally balanced concentrate diet in these production systems (Staal and Shapiro, 1996). In addition, there is no quality controlling system to regulate the nutrient compositions of commercially formulated concentrate in the way it can fulfill the nutrient requirements of dairy animals in different productive states. This can be one of the major factors to limit the expression of genetic potentials of exotic dairy cattle. Generally, information on the nutrient composition of the available feed resources and its influences on the productive and reproductive potential of urban and peri-urban dairy farms are also limited and needs assessment.

Cottonseed cake is one of the alternative sources of protein supplement used mainly in fattening operations in Ethiopia. It has relatively low rumen degradability and is, therefore, a good source of bypass protein. However, it is rarely used in current commercial dairy farming systems in the country. Documented information on the effect of cottonseed cake inclusion in a concentrate diet on postpartum productive and reproductive performance, and profitability in lactating dairy cattle is scarce and needs assessment. Further more, research efforts made so far did not consider much about the cost-benefit relationships of different management practices for improvements of productivity; but only biological indicators such as yield, growth rate, etc., were used as measures of success (EARO, 1998a).

In addition, levels of essential minerals in most commonly used fibrous feed resources were also studied and reported to be deficient to marginal (Kabaija and Little, 1989). Evaluation of mineral compositions of locally produced oilseed cakes has also indicated that the concentration of P, K and Mg are higher than optimum level for ruminant diets but low in Ca and Na contents (Solomon, 1992). But biological availability of minerals for utilization is influenced by the level of fiber in the feed because of its association with some indigestible fibers (Kabaija and Little, 1989). The existing animal feed processing firms in Ethiopia include limestone as a mineral source depending upon availability. Common salt (sodium chloride) is mainly included in a concentrate mix. Lake soils in the Rift Valley of Oromia are suspected to contain a number of macro and micro-minerals. Farmers traditionally water their animals periodically and feed them lake soils (bole), believing that this would improve the productivity of animals in terms of growth and fertility (Mohamed *et al.,* 1991). Investigation by Mohamed *et al.* (1991) indicated that there was no significant difference on daily weight gain between Arsi sheep supplemented with lake soils from different sources and the control (un supplemented) group. Chemical analysis of these lake soils also indicated very low Ca and P level except the red soil, which had high level of P. However, information on the influence of these lake soils on milk yield, milk compositions and reproductive performances of dairy cattle is scarce and needs further investigation.

Objectives

General Objective

To evaluate the influences of available feed resources and feeding managements on productive and reproductive responses of dairy cattle.

Specific objectives

1. To assess productive and reproductive performance of lactating dairy cows under small and large scale farmers' management systems in central Rift Valley of Oromia.
2. To relate available nutrients intake on-farm with productive and reproductive responses of dairy cows under farmers' management.
3. To evaluate postpartum productive and reproductive responses of lactating cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.
4. To evaluate the effects of certain dietary minerals intake on reproductive responses of lactating dairy cattle.

LITERATURE REVIEW

The potentials of exotic cattle breeds in the tropics

Milk production

Milk yield is a product of animal genetic and environmental interactions (Johnson, 1991). Milk yield for specific genotype is the function of climate and its interactive influences on the quantity and quality of feeds, the presence of disease and parasite and the utilization of technology to alleviate nutritional, thermal and health limitations. Milk production systems in the tropics are diverse. At one extreme the systems are similar to those in most industrialized countries and are based on cows of high genetic potential given "high quality feeds" which includes fodder crops/silage, grain and protein concentrates (Leng, 1991). Milk production per cow is extremely high and technological inputs are high. Under some tropical feeding and management conditions a ¾ or pure Holstein-Friesian cows could produce over 4,000 kg of milk per lactation (McDowell, 1985; Combellas, 1981). In India, Friesian cattle breeds had produced an average of 6000 kg milk in 300 days of lactation with appropriate nutritional management practices proposed by Leng and Kunju (1989); cited by Leng (1999). This achievement was recorded by supplementation practices of 30% bypass protein with approximately 75% of the protein in the form likely to bypass the rumen. In Malawi, Mussa *et al.* (1987) reported that crossbred (Friesian x Zebu) cattle in different locations produced 16–18 kg/day of milk when supplemented with concentrate diet consisting different levels of cotton seed cakes.

At the other extreme are systems which are used by the vast majority of small farmers in developing countries and are based on low inputs and productivity per cow is relatively low. Even in some specialized large scale farms lactation milk yield of pure Holstein cows is far below their expected genetic potential. In Ethiopia, efforts to improve the level of milk production and fill the gap for high milk demand was started before the Second World War when some Channel Islands and Friesian cattle breeds were introduced by individuals and religious organization (Abaye *et. al*., 1991). But the productivity of these cattle breeds was far below expectation. Sendros and Tesfaye (1998) reported that, lactation milk yield of Holstein-Friesian cattle on large-scale commercial state dairy farms couldn't exceed 3000kg. Significant variation was also observed between years which may be attributed to inconsistent management practices in terms of proper nutritional supply (Kiwuwa *et. al.,* 1983; Melaku, 1994; Goshu and Mekonen, 1997; Nega and Sendros, 2000). Nutritional imbalance, diseases and environmental factors are important constraints of milk production and reproduction in the tropics (Preston and Leng, 1987; Mukassa, 1989). These factors limit the expression of their genetic potentials.

The large variation in the productivities of exotic cattle breeds in different regions of the tropics with similar environment indicates that there are opportunities for improvement through appropriate management practices. Therefore, developing appropriate management and feeding norms may enable dairy farmers to exploit the potentials of exotic dairy cattle breeds under tropical environment.

Reproduction and Health

Reproductive performance is a trait of outstanding importance in dairy cattle enterprises. It is one of the major factors, which determine the efficiency of animal production (Perera, 1999). The size of the calf crop is all-important for herd replacement, and the production of milk depends heavily on reproductive activity. Possible genetic improvement in virtually all traits of economic importance is closely tied to reproductive rate.

Infertility is one of the most important economic losses in high producing dairy cows (Lanyasunya *et al*., 2005). Low fertility rate, low milk yield and high mortality rate resulted in high financial losses is common phenomenon of running commercial dairy operations using pure or graded exotic breeds in the tropics (Abaye *et. al.,* 1991). Though, these losses are largely attributed to health related factors such as metritis, retained placenta, silent estrus, cystic follicles repeat breeding and abortions, poor feeding and management have often predisposed cows to infertility causing factors (Lanyasunya *et al*., 2005). Inefficient reproduction decreases profitability of a farm by reducing both the efficiency of milk production and the number of available replacement heifers (Kiwuwa *et al.,* 1983; Perera, 1999). Availability of balanced energy-protein, minerals and vitamins are important factors determining both productivity and reproductive performances of dairy cattle.

Ideally, a dairy cow should calve at yearly interval and should have a lactation length of 300 days; but in practice calving intervals are often longer or lactation periods are shorter in the tropics (Ranjhan, 1999). Under many dairy production systems in the tropical countries, a one-year calving interval is often difficult to achieve (Perera, 1999). Although, the genotype of the animal can determine its reproductive potential the environment influences the end result. A well-adapted tropical zebu cow might have a relatively low inherent reproductive capacity, but may be able to achieve its full potential under the prevailing conditions. On the other hand Holstein-Friesian cows which have been bred for high milk production and excellent reproductive performance under temperate conditions perform below its genetic potential when moved to the tropical environment (Perera, 1999). These differences exist not only between the European and tropical cattle breeds, but also between, for instance, Asian and African cattle breeds of Zebu. Inappropriate nutritional supply is one of the major factors to limit their productive and reproductive potentials (Mukassa, 1989; Preston and Leng, 1987). Generally, in the tropical countries, environmental factors such as high heat and humidity and seasonal variations in feed availability can have important influences on reproductive performance of cattle. Moreover, in confined management systems, the efficiency of heat detection, timing of services and other related factors can influence reproductive efficiency of dairy cattle.

Apart from climatic stress, infectious diseases and parasites such as FMD, tuberculosis, foot rot, flies, liver, flukes, round worms and ticks are more prevalent and common problems of dairying in the tropics. Knowledge concerning dairy herd management such as barn type, feeding methods, waste management, and calf feeding and care, in relation to tropical conditions, is lacking. Western technologies in these areas have been proven to be mostly impractical for developing countries, due to differences in socio-economic and climatic factors (Chantalakhana, 1999). Improvements of dairy management practices require much research.

The role of by-pass protein sources on performances of dairy cattle.

Effects on milk yield and composition

The productivity of ruminants is influenced primarily by feed intake, which in turn is determined by the digestibility of the feed and the capacity of the diet to supply the correct balance of nutrients required by the animal in different productive state (Preston and Leng, 1987). As feed intake increases the nutrient potentially available for bacterial growth increases so that total bacterial protein synthesis is likely to be increased.

Although, increased intake is generally reflected in greater bacterial protein flow to the intestine, bacterial protein is not produced in sufficient quantity to meet the requirement of dairy cows, especially in early lactation. Inclusion of protein that escapes ruminal degradation is required for maximizing production (NRC, 1989; Maiga and Schingoethe, 1997). This can supplement the bacterial protein being supplied for digestion in the small intestine. The origin of protein entering the small intestine from the rumen is largely microbial protein. But when protein supplements are given to ruminants, some proteins depending up on protein sources and feeding levels will escape degradation and enter the small intestine in undegraded form (Ørskov, 1991). Influences of supplementing different forms and levels of rumen escape protein (RUP) sources on milk yield and composition, in dairy cattle was investigated by several workers and inconsistent results were reported.

Atwal *et al.* (1995) reported that, treated soybean meal (TSBM) supplementation significantly increased milk yield and persistency than untreated soybean meal (SBM) during 7 to 16 weeks of lactation in Holstein Friesian cows. The use of TSBM also increased daily production of milk protein; fat and lactose by 25.6, 54.2 and 76.3g respectively, but these differences were not statistically significant. Similarly, the effect of CP percent was not also significant. The higher digestibility of the CP for the TSBM diet at 17% CP compared with 15% CP supports the hypotheses that the major effect of TSBM on CP digestibility was due to a limited supply of RDP (Atwal *et al.,* 1995).

In a study by Cunningham *et al.* (1996) on the influences of 16.5% and 18.5% levels of CP with either 30% or 60% rumen un-degradable protein, the response to dietary RUP content appeared to be affected by parity and dietary CP concentration. Yield of 4% FCM, milk fat and milk protein increased as dietary CP increased. Increased RUP, especially the diet containing high RUP and 18.5% CP tended to increase yield of milk, 4% FCM, milk fat and milk protein, perhaps because of increased flow of essential amino acids (EAA) that were critical for milk protein synthesis.

In crossbred dairy cows in the forth months of lactation, the effects of supplementing 5 levels (0, 1, 2, 3, and 4kg) of bypass protein on straw based basal diet indicated that milk production and body weight gain was linearly increased in accordance with the level of bypass protein (Kunju *et al.,* 1992). The maximum response was noticed in cows that were fed 3 kg by-pass protein. However, further response was not obtained in the cows fed 4 kg by-pass protein. It is assumed that the efficiency of nutrient utilization was increased owing to increase in protein to energy ratio through feeding both rumen fermentable and by-pass protein. The animals given additional 1kg by-pass protein feed yielded 1.2 kg more milk than the animals fed no bypass protein. But those animals lost their body weight on an average of 120 and 80 g/d respectively.

In India, supplementing a concentrate mixture containing 35% RUP in CP or 50% RUP in CP for crossbred dairy cows in 2 to 5 lactation, FCM yield was higher (9.4 kg) for those supplemented with 50% RUP than those supplemented with 35% RUP (7.8 kg) (Sampath *et al.,* 1997). This could be attributed to higher availability of post-ruminal digestible protein, enabling higher production performance. In this work since the levels of RDP were maintained similar in both groups and the only factor, which was variable, was RUP, the enhanced milk yield was solely attributed to the higher levels of RUP. In crossbred (Holstein Friesian x Sahiwal) cows within 40 to 60 days postpartum, supplementing a concentrate mixture varying in RDP to RUP ratio showed no significant difference on milk yield and solid corrected milk (SCM) yield (Chaturvedi and Walli, 2000). However, FCM yield (Kg/d) was higher ($p<0.05$) in 44:56 of RDP: RUP ratio than the 71:29 and 58:42 ratio. Such trend in FCM yield could be explained as due to the increase in milk fat percentage as a result of feeding higher RUP diets. Except Solids-not-fat (SNF) content the rest of milk components. (Fat, protein and total solids) differed significantly ($p<0.01$) among treatments, and all the milk components showed increasing trend with increased ratio of RUP in the diet (Chaturvedi and Walli, 2000; Robinson *et al.,* 1991; Winsryg *et al.,* 1991). The higher ($p<0.01$) milk fat percent in the group fed the diet with the ratio of 44:56 RUP could be attributed to the higher proportion of corn gluten meal in that diet and this agrees with the reports of Kim *et al*. (1991).

Wohlt *et al.* (1991) evaluated the effects of supplementing the basal feed of corn silage (CS) and grain with 12% CP (control), supplemented with either 16% CP Soybean meal (SBM), 16% CP fish meal (FM) or 16% CP corn gluten meal (CGM) on milk yield and composition of cows. Average milk yield during weeks 4 to 18 were 29, 36, 39, and 34 kg/d respectively. Milk yield was greater for cows fed 16% CP diets than 12% CP ($P<0.01$) and for cows fed FM vs. CGM ($P<0.03$). Daily milk protein yield among treatment groups did not differ. Level and sources of dietary crude protein had little effect on milk protein test; however, average daily milk protein yield was less ($P<0.006$) for cows fed 12% CP vs. 16% CP (906 vs. 1098 g/d). Similarly average daily milk fat yield was less ($p<0.03$) for cows fed 12% CP vs. 16% CP (958 vs. 1141 g/d). Sources of supplemental CP is also an important factor as average milk protein yields were 113 and 133 gm greater for cows fed SBM and FM, respectively than for cows fed CGM. Differences in milk yield in response to level and sources of dietary CP are the major factor influencing milk protein yield. Variation in yields of milk and milk protein, and losses of body weight in cows fed 16% CP SBM, 16% CP FM, and 16% CP CGM were in response to differences in the utilization of N from SBM, FM and CGM. Urinary N as a percentage of absorbed N tended to be lower for cows fed FM (38%), intermediate for cows fed SBM (42%) and higher for cows fed CGM (46%). The differences between SBM and FM may have been a result of differences in degradability, because SBM was more degradable in the rumen than FM (Wohlt *et al.*, 1991). Cows fed on 16% CP SBM and 16% CP FM had greater over all DM intake of 21.2 and 20.8 kg respectively than those fed on 12% CP (19 kg) and 16% CP CGM (19.8 kg) (Wohlt *et al.,* 1991). Corn gluten meal was an inferior source of protein relative to FM and SBM for high producing dairy cows. Although, it supported a higher level of milk yield than the 12% CP diet, it resulted in higher body weight loss through 18 weeks lactation. Milk yield tended to be higher, persistency greater and body weight loss less when cows were fed FM vs. SBM during 5 to 18 weeks of lactation, but the milk fat depression was occurred when FM was fed at 7% of the dry matter.

Feeding strategies may require that CGM be complemented by other protein sources in providing an acceptable un-degradable amino acids pattern to the high producing dairy cows (Wohlt *et al.,* 1991). Even though, SBM was low in undegradable CP compared with FM (25% vs. 65%), production responses by cows fed SBM did not differ dramatically from those fed FM. In cows fed 12% CP and 16% CP CGM, insufficient peptides and amino acids may have limited microbial fermentation and synthesis in the rumen, contributing to lower apparent digestion of the dry matter. The improved digestibility and intake of DM in the cows fed SBM and FM may have been in response to available peptides and amino acids.

In contrast to the above reports, other workers reported that, varying the source and amounts of protein did not significantly alter the yield and composition of milk. Lactation performances of multiparous Holstein cows supplemented CP sources of SBM, wheat germ, wheat shorts, meat meal, and urea as low RUP, and blood meal, fish meal, corn gluten meal, meat meal, feather meal and urea as high RUP sources, both containing either 16.4% or 19.4% CP and either 30% or 45% RUP were evaluated by Christensen *et al*. (1993). Intake of DM, ADF, and NDF, and body weight changes were not different among treatments. However, DM intake for cows fed the high CP and high RUP diet was slightly lower than for cows fed the other diets. Production of milk and 4% FCM was not altered by either CP intake or degradability of the CP in the diet. Increasing the CP content of the diet did not affect either the percentage or production of fat in milk. When cows were fed diets high in RUP, the percentage of fat in milk was increased ($p<0.03$), but production of milk fat was not altered. Substitution of RUP for RDP has altered both percentage and production of milk components. Milk fat percentage was depressed when fishmeal replaced soybean meal as the source of supplemental protein.

Zimmerman *et al*. (1992) also evaluated the effect of low protein (14.4% CP) untreated SBM (LPU), high protein (18.7% CP) untreated SBM (HPU) or high protein (18.7% CP) with soybean meal enhanced with rumen undegradable protein (HPT) in multiparous and primiparous cows. Feed intake, milk yield and composition were not affected by treatments in multiparous cows. However, milk yield was higher for HPT than for LPU in primiparous cows. Yield of milk protein and SNF also followed the increase in milk yield. A basal ration containing SBM (control) as its primary degradable protein source and CGM, and meat and bone meal ration as the primary undegradable protein source representing 30% RUP in CP did not influence the performances of lactating multiparous Holstein cows in early lactation (Winsryg *et al.,* 1991). Protein sources (degradability) did not influence mean daily milk yield. Production efficiency (3.5 FCM/kg DM intake) was not significantly different between treatments, but tended to be higher ($p<0.10$) for cows fed SBM (2.56 vs. 2.39 FCM/kg DMI). Percentage of milk fat and SNF were not significantly different between treatments, but percentage of lactose was significantly increased for cows fed SBM diet, over the CGM, and meat and bone meal diet (5 vs. 4.91). Total milk protein and casein were significantly increased by higher protein un-degradability (3.14 vs. 2.86 and 62.11 vs. 58.24 respectively). Total tract apparent digestibilities of the nutrients in the ration were not affected by treatments. The percentages of CP, ADF and NDF were similar for both treatment and the control. However, the CP digestibility of animals fed the CGM, and meat and bone meal diets tended to be higher ($P<0.08$) than that of cattle fed SBM (67.85 vs. 62.83). In this study, the animals were 60 days postpartum at the initiation of the project. At peak lactation intake appears to be depressed relative to increased milk production. Feed intake or body weight gain with either of the protein sources, SBM or CGM, and meat and bone meal were not affected. The CP in both experimental rations was low (14.5%) compared with the NRC (1985) requirements for animals at that stage of lactation (17 to 18%). Therefore, a decreased in intake and decrease in CP% in the diet could decrease ruminal microbial synthesis.

Responses of lactating cows to different forms of cottonseed supplementation were also evaluated by different workers. Although works done on the animal performance evaluation of cottonseed cake is so far limited in Ethiopia; Yohanes *et al.* (unpublished data) recently evaluated the effects of three types of concentrate mixtures composing of cottonseed cake (40%), wheat bran (58%), common salt (1%) and bone meal (1%) (Ration 1); nougseed (*Guizota abyssinica*) cake (30%), wheat bran (67%), common salt (1%) and bone meal (2%) (Ration 2) or a commercially formulated concentrate diet consisting of wheat bran (30%), wheat middling (31%), nougseed cake (35%), common salt (1%) and bone meal (3%) (Ration 3). The result indicated that diet with cottonseed cake did not improve either dry matter intake or milk yield of crossbred dairy cattle. In addition longer days (126) from calving to first service were observed as compared to animals fed the commercially formulated concentrate (111 d) and nougseed based concentrate diets (99 d). The influences of these dietary treatments on milk composition were not reported in this study.

Belibasakis and Tsirgogianni (1995) compared the effects including either 14% cottonseed meal or 20 % whole cottonseed on milk yield and milk compositions of dairy cows in hot weather of Greece. The result revealed that DM intake, milk protein content and yield, as well as milk lactose and total solids were not affected by treatments. In contrast, whole cottonseed supplementation increased daily actual milk yield (25.1 vs. 23.1 kg; $p<0.05$), 4 % fat corrected milk yield (25.0 vs. 21.5 kg; $p<0.05$), milk fat content (3.98 vs. 3.56%; $p<0.05$) and milk fat yield (1.0 vs. 0.82 kg; $p<0.05$). Boodoo *et al*. (1990) in Mauritius reported that replacing 50% of commercially formulated concentrate diet with cottonseed cake had no significant effects on milk yield and milk protein content of dairy cows fed on basal diets of sugar cane tops and grass hay. Another work by Smith *et al.* (1981) revealed that substitution of total mixed ration with different levels of whole cottonseed cake did not significantly affect DM intake or milk yield of Holstein Friesian cows, but increased milk fat and FC milk yield. Abu-Baker (2002) also reported that replacing maize and soybean meals with 30% full-fat cottonseed linearly decreased dietary DM intake, milk yield and protein contents of Friesian cows fed maize silage and alfalfa haylage. But milk fat content was significantly increased by inclusion of cottonseed cake. Effects of utilizing cottonseed meal alone or in combination with forage legume trees on milk yield and composition of dairy cows was also reported by different workers. Sarwatt *et al.* (2004) reported that daily milk yield was lower when cottonseed meal alone was included in a concentrate diet than it was with *Moringa oleifera* foliage. However, the combination of cottonseed meal (0.8kg/d/head) with Moringa oleifera forage (0.55kg/d/head) in a concentrate diet significantly increased daily milk yield of cows. But the compositions of milk were not affected by treatments. Similar work by Shem *et al.* (2003) also revealed that daily DM intake and milk yield of cows supplemented with CSC alone or in combination with *Gliricidia sepium* was higher than those supplemented with *Gliricidia sepium* alone. Alike the report by Sarwatt *et al.* (2004) the compositions of milk were not affected by treatments.

Nocek and Russell (1988) postulated that the failure of ruminally insoluble or undegradable protein to increase milk production in some trials may have resulted because: first, dietary protein exceeded the cows requirement for protein, second, RUP was fed that was poorly digested in the small intestine, thirdly, unforeseen interactions occurred with mobilization or utilization of nutrients from body tissues, or forth, a depression in microbial protein synthesis in the rumen resulted from lowered concentration of ruminal ammonia. From their summary of literature Nocek and Russell (1988) suggested that dietary incorporation of supplemental protein sources that are high in RUP stimulates milk production when CP intake is marginal (<14% CP), but not when dietary CP exceeds 16%. Highly protected RUP (89.4% of CP) was also found to provide very little RDP and this limitation of RDP significantly decrease digestibility of DM, CP and ADF. Source of supplemental CP is also an important factor to influence the response of animals, due to their variation in type and levels of EAA contents. For example, since blood meal is deficient in methionine, it must be combined with RUP sources rich in mehionine, such as corn gluten meal (CGM) and fishmeal (FM). Blood meal and CGM contain high concentration of lysine and methionine respectively. Therefore, supplementation with these RUP sources can improve their availability through increased flow to the lower gut.

Effects on reproductive efficiencies

Animal nutritionists and veterinarians have for some years expressed divergent opinions as to the possible influences that dietary protein type and quantity (total protein percentage) might have on the over all reproductive efficiencies of high producing dairy cows (Muller and D'yvoy, 2000). Several workers (Gould, 1969; Jordan and Swanson, 1979a; Jordan and Swanson, 1979b) expressed suspicions that a high dietary protein intake during early lactation may have some detrimental effects on fertility. Although present knowledge allows for reasonably high CP level during early lactation, there are still some differences of opinions on the optimum dietary CP concentration as well as the effect on milk yield and reproductive efficiency with changes in the total protein intake. Gould (1969) first reported a reduced fertility in dairy cows, when more than 1.84 to 1.93 kg digestible proteins per day were fed. Anoestrous was increased while conceptions rate and peak milk yield were decreased.

Jordan and Swanson (1979a) reported that cows fed excess total protein (19.3% CP on DM basis) produced more milk (30 kg/d) as compared to two groups of cows each received 16.3 and 12.7% CP, all diets being similar in calculated total digestible nutrient (TDN) content. Cows fed higher level of protein showed signs of standing oestrus earlier after calving. However, they tended to have lower conception rate and consequently were open longer and required more services per conception. In their follow up study, Jordan and Swanson (1979b) reported that a high dietary protein intake also influenced the plasma concentration of luteinizing hormone (LH) and progesterone. Cows fed a ration containing 12.7% CP had lower blood serum LH concentrations compared to cows received ration containing 16.3% and 19.3% CP. It was apparent that a linear decline of LH with time occurred in cows, which became pregnant, whereas serum LH remained unchanged in non-pregnant cows.

The mechanism of action by which high protein intake may affect fertility is as yet uncertain (Kaim *et al*., 1983). Several theories as to the possible causative factors have been put forward and reviewed by Muller and D'yvoy (2000). Excessive intake of protein may cause ruminal alkalosis and increased rumen ammonia concentration (Satter and Roffler, 1975). Generally the main site for ammonia absorption is the ruminal and omasal epithelium from where the ammonia is collected in to the blood via the portal system and transported to liver to be detoxified, i.e., converted to urea (Davidovich *et al.,* 1977; Folman *et al.,* 1981). Cows fed a ration containing 20% CP had significantly higher plasma ammonia and urea level than cows receiving 16% CP diet. The higher plasma ammonia concentration as observed by Jordan *et al.* (1983) suggests that the enzymes of the urea cycle were unable to convert all of the excess ruminal ammonia in to urea N, possibly because uptake in to the hepatic cells was insufficient. Increased concentration of ammonia could have detrimental effects on fertility, because it is toxic to mammalian cells. To minimize the production of the dangerous levels of ammonia, rapid ruminal degradation of the protein diets have to be protected or those naturally protected have to be utilized.
Folman *et al.* (1981) in Israel compared three groups of 20 multiparous high producing cows fed diets containing different levels of SBM. Two groups received either 16 or 20% CP SBM diets while the third group received 16% CP formaldehyde treated for 122 days of lactation. Days from parturition to first oestrus did not significantly differed ($p>0.05$) between groups. However, for cows fed a diet containing protected SBM, conception rates were higher and fewer days open were recorded. Cows fed a ration containing 16% CP (formaldehyde treated SBM) had lower concentration of rumen liquor ammonia than cows fed 16% CP untreated SBM diet. The former treatment group showed a tendency to higher fertility by having a higher conception rate. Kaim *et al* (1983) in Israel reported that high yielding dairy cows supplemented with high protein (HP) diet had lower conception rate (43%) as compared to those supplemented with low protein (LP) diet (57%).

Factors affecting the profitability of dairying in the tropics

Livestock production requires making of appropriate decision in a complex environment that minimizes costs of production and maximizes profit at a specified level of output, subject to various technical and economic constraints. Farmers' use of various levels of inputs for livestock production is greatly influenced by their economic circumstances (EARO, 1989). The efficiency of milk production (E) is a function of income from a farm output (A), mainly from milk sale and costs of milk production (B). Therefore, in order to increase the efficiency of a farm, one needs to increase output and reduce costs of inputs (Chantalakhana, 1999). Improved genetic potential of the animals and cost effective feeding practices are among the major prerequisites for profitability of dairy enterprises. Feed cost accounts for about two-third of the total cost of milk production (De Boer, 1999). In order to increase milk yield/cow, dairy cows with a high genetic potential for milk production have to be chosen. Only better management and feeding practices can realize the productivity and profitability of a farm (Chantalakhana, 1999).

The role of minerals in dairy cattle nutrition

Proper mineral nutrition and supplementation is essential to animal health and high level of milk production (Harris *et al.,* 1994). Mineral elements which are required by dairy cattle are grouped in to two main categories according to the amounts required by the animal. Those in the first category are the major minerals Ca, P, Na, Mg, K, and S, and the second category called trace minerals includes Fe, Cu, Mo, Mn, Zn, Co, I, and Se. Under normal conditions, the minerals, which are most likely to be needed by the cow in greater amounts, than provided by common rations are Ca, P, Na and Cl. Steamed bone-meal, dicalcium phosphate, and limestone may be used to supply ca, while dicalcium phosphate, monocalcium phosphate, and monosodium phosphate may be used to supply P (Harris *et al.,* 1994). The net daily maintenance requirement of Ca for the dairy cow is generally accepted to be about 16 mg/kg body weight, while P requirement is varying from levels of 14 to 28 g/kg body weight (McDonald *et al*., 1988) for animals of about 500 kg live weight. However, some evidences from feeding trials on P requirement support a value of 14.5 g/kg live weight. Calcium and phosphorus are closely related elements and are found in bone in a ratio of 2.2:1 (Harris *et al.,* 1994; McDowell, 1997). This means that a deficiency or an overabundance of either mineral could interfere with the proper utilization of the other. An imbalance of either mineral can cause them to bind with each other and become unavailable to the animal.

Most of the diets of ruminant consists plant materials. The amount of minerals present in the plants depends upon the mineral status of the soil on which the herbage grow, the ability of the plant to absorb them and the stage of growth of the plant. The levels of minerals can even vary from field to field on the same farm (Chesworth and Guérin, 1992; Preston and Leng, 1987). Therefore, it is very difficult to give average values for the amount of minerals which might be expected from feeds. Grains are low in calcium content but higher in phosphorus. Legumes usually are good sources of calcium but not phosphorus, and grasses are much lower in calcium than legumes (Schroeder, 2004).

In addition to the requirement for maintenance, Ca and P must be provided for milk production. The concentration of the two elements in the milk of dairy cows represents the net requirements for milk production. In order to estimate the dietary requirements of the elements, it is necessary to know their availability from the dietary supplies. Their availability and utilization is influenced by the level of fiber in the feed, because of its association with some indigestible fibers (Kabaija and Little, 1989). Diets with lower mineral availability *in vivo* have much of their intrinsic minerals in association with fecal fibers, which may not be removed by water (Kabaija and Little, 1989). Some evidences show the availability of Ca and P to be 0.68 and 0.58 respectively (McDonald *et. al.,* 1988). Based on this evidence, it was proved that, 25 to 28 g of Ca and 25 g of P per day to be adequate for a cow producing 4540 kg of milk per annum. This implies a dietary requirement of 1.10 to 1.32g Ca and 1.10 g P per kg of milk.

A lactating animal responds to a dietary deficiency of Ca or P by reducing its yield of milk without affecting the concentration of the minerals in the milk produced. Even in the extreme deficiency, the composition of milk in these respects remains within normal limits. In the early stages of the deficiency, or where the deficiency is moderate, the animal is able to draw on its skeletal reserves of Ca and P to maintain yield. Several successive lactation may be needed before bone defect and other clinical signs become obvious and milk production impaired (Underwood, 1981).

In areas where P deficiency was severe and prolonged, as occurred in parts of South Africa, striking evidence of its effect on milk yield in cows was observed, and increase in milk yield from 40 to 140% were recorded from the use of bone-meal supplements (Underwood, 1981). Bone meal can also provide an appreciable supplement of protein, which may support the increase in milk production (Underwood, 1981). However, in an experiment with beef cows in which the dietary protein was adequate, P deficiency imposed during the late pregnancy and early lactation induced a significant depression of milk yield (Underwood, 1981).

Poor calf crops have been a regular feature of herds confined to P-deficient grazing (Underwood, 1981). In a study of breeding cattle only 51% produced calves in the untreated groups, compared with 80% in comparable animals receiving a bone-meal supplement (Underwood, 1981). The subnormal fertility was associated with depressed or irregular oestrus preventing or delaying conception. In dairy cows mated during full lactation and with slightly subnormal inorganic phosphate contents in their blood delayed conception causing temporary infertility has been observed (Snock, 1958; cit. Underwood, 1981). Improved fertility has been also reported (Underwood, 1981) in dairy cows with subnormal serum phosphate after defluorinated super-phosphate was added to the drinking water. The first service pregnancy rate increased from 36.5 to 63.2% and the mean calving to conception interval decreased from 109 to 85 days. On the other hand no evidence of adverse effect on age at puberty or pregnancy rate was obtained with Hereford heifers fed on low P (0.14%) diet for two years (Call *et al.,* 1978); or on conception rate in older beef cows given an even more deficient diet (0.09%) for the last two-third of pregnancy (Butcher *et. al.*, 1980; cit.

Underwood, 1981). Srivastava and Sahni (2000) reported that cows and buffaloes with higher blood phosphorus concentration 4.16 and 4.96 (mg/100ml) had higher conception rate than those with lower blood phosphorus concentration 3.6 and 3.4 respectively.

In Ethiopia, inadequate animal evaluation and response trials have been carried on crop residues, agro-industrial by-products and other non-conventional fed resources. Moreover research work on these feed resources with relatively better comprehension has been confined to Holeta Research Centre (EARO, 1998b). Limited feeding trials conducted at other centers, were not supported by quantitative (intake of basal diet and supplement) and qualitative data (nutrient composition). Consequently, the development of feeding system based on physiological state of animals has not been obtained. Studies on nutrient requirement, digestive physiology, rumen ecology microbiology and nutrient requirements were not undertaken virtually for all classes of animals under local condition.

MTERIALS AND METHODS

Experiment 1: Comparative performances of Holstein Friesian cows under smallholder and large scale farmers' management in central Rift-Valley of Oromia, Ethiopia

Study area

This study was conducted in the Central Rift Valley (CRV) of Oromia, at Arsi Negelle, Ziway, Wonji Kuriftu and Lume districts of East Shoa Zone. East Shoa Zone (Figure 1) is located between $38^{o}00'$E to $40^{o}00'$E longitude and $7^{o}00'$N to $9^{o}00'$N latitude. It is characterized with different altitude ranges of 1550 to 1900 meters above sea level and average minimum and maximum temperature of 20^{o}C and 27^{o}C respectively. It has an erratic and unreliable rainfall, ranging from 500 to 900 mm per year.

Eastern Shoa zone is one of the 12 zones of Oromia state. The human population of the zone is estimated to about 1.8 million, of which about 72 percent is living in the rural area. The land area of the zone is about 1.4 million hectares and utilized for agriculture (38.4%), grazing (14.3%), and forest (14.5%) and not cultivated (3.8%). The farming system in the area is mostly mixed farming with the exception of one district in the lowland area being dominated by semi-nomadic activities. In the mixed farming system crops such as maize, tef (*Eragrostis abyssinica*), wheat, barley, sorghum, haricot bean, pulses, fruits and vegetables are grown (SPM, 1999).

Livestock rearing is also important for livelihood of the people in the area. According to estimate of CSA (2003) the livestock population of East Shoa zone includes, 1,416,551 cattle; 270, 388 sheep; 516,498 goats; 25,360 horses; 261,710 donkeys; 10293 mules; 38,731 camels; 1,313,345 poultry and 65,085 beehives. About 2,418 heads of exotic and 4,540 heads of crossbred cattle breeds are found in the zone.

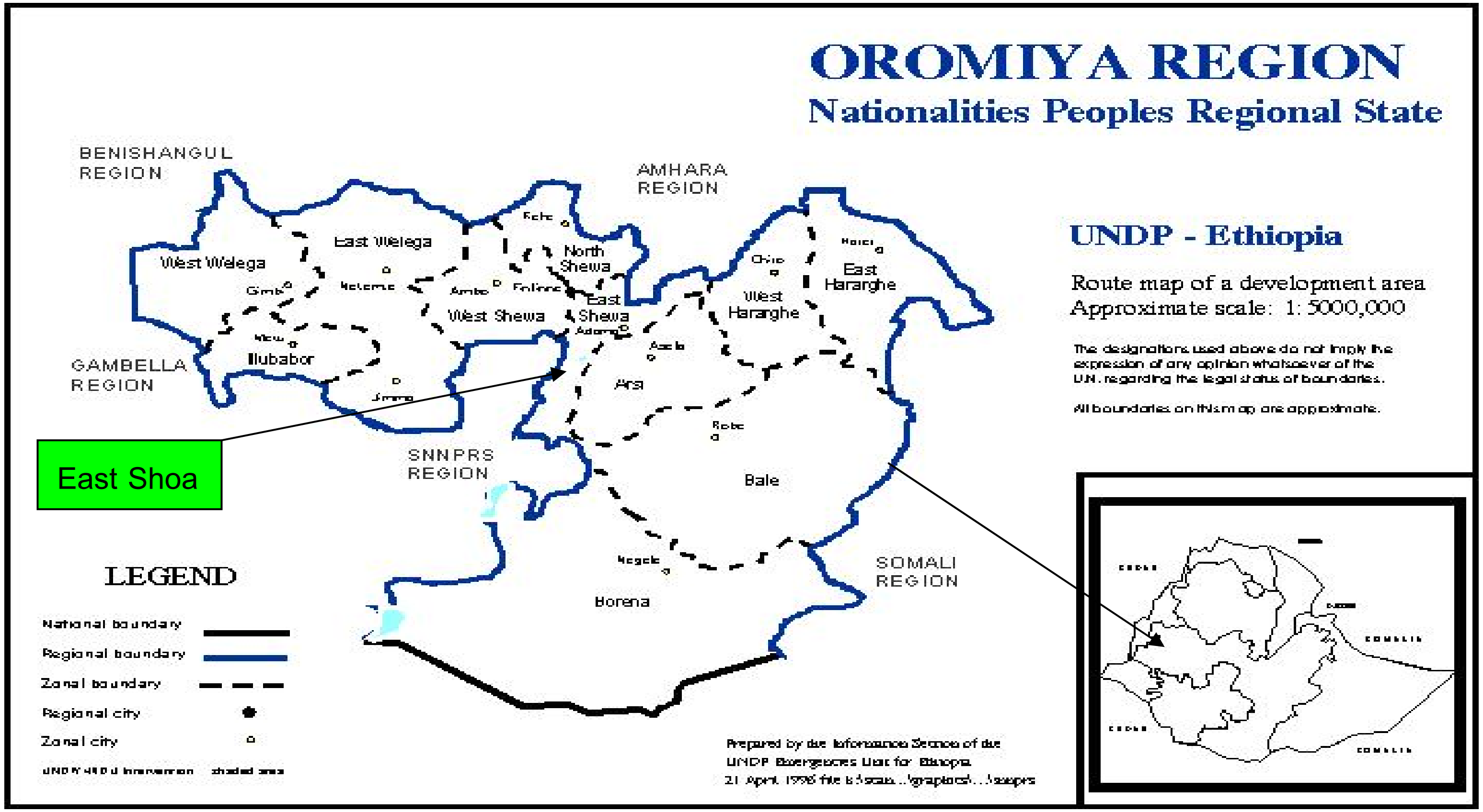


Figure 1 Map of East Shoa Zone, Oromia State.

Source: UNDP (1996)

Sampling and animal management

A rapid exploratory survey was undertaken to identify and locate the existing large and small scale dairy farms in the urban and peri-urban centers of the study area. Based on the willingness of the farm owners, the presence of dairy cows of graded Holstein-Friesian genotype, known parity and stage of pregnancy, 3 large peri-urban farms having 170 to 195 heads of dairy animals and 21 small scale urban farmers in the secondary towns having 1 to 10 heads of cattle were identified.

The farms were categorized based on the existing herd size as small scale (≤10 animals) and large scale (>10 animals). Accordingly, two large scale farms and 12 smallholder farmers were randomly selected. A total of 28 animals from both large scale (14 animals with 426±85 kg average body weight) and small scale (14 animals with 363±8.5 kg average body weight) with the parity ranging from 1 to 6 and in the last trimester of pregnancy were used for data collection. Animals in different parities were classified as early parity (1-2 lactations) and advanced parity (3-6 lactation). Seven animals were used in each parity class.

In the urban small scale production system the animals are entirely confined at home utilizing whatever space is available in the residential compounds (Figure 2). There were no sufficient exercising areas for animals. Animal houses and feeding facilities on small scale farms were poor relative to that of large scale farms (Figure 3). They were normally small structures of corrugated metal sheeting or mud and floored with blocks of stone or cemented floor.

Figure 2 Dairy animals confined in the residential compounds on smallholder farms in the urban centers.

Figure 3 Poor housing structures and feeding facilities on small scale farms.

Purchased and preserved crop residues, such as maize stover, haricot bean straw, tef (*Eragrostis abyssinica*) straw and wheat straw (Figure 4a) were the major basal feed resources.Green forages of maize (Figure 4b) and native grass were also used seasonally. Manually chopped green maize forage was fed to the animals after the ears were removed for human consumption. The utilization of agro-industrial by-products such as nougseed cake (*Guizota abyssinica*), linseed cake, cotton seed cake and wheat bran was minimal. Most of the smallholder farmers used to mix these agro-industrial by products mainly depending upon availability and economic circumstances of individual farmer. But some of them still feed their animals separate ingredient of wheat bran, nougseed cake or linseed cake if available. None of the farmers was observed using mineral supplements and if there were any, very few were restricted in using only common salt

Figure 4 Typical basal diets of (a) wheat straw (Arsi Negelle) and (b) maize forage (Ziway) for small scale urban dairy farmers in central Rift Valley, Oromia.

In the peri-urban large scale production sub-units animals were housed in sheds with well ventilated corrugated metal sheet and cemented floors (Figure 5). Their major basal feed source was based on purchased or very few harvested native grass hay. Green feeds of alfalfa and elephant grass were also used (Figure 6).

Figure 5 Relatively improved housing structures and feeding facilities on large scale peri-urban dairy farms.

Figure 6 Green forages of alfalfa and elephant grass on peri-urban large scale dairy farms in central Rift Valley, Oromia.

There was regular supply of mixed concentrate diet (Figure 7). Large scale farms under this study were observed preparing their own concentrate mix from purchased nougseed cake and cereal crop screenings of wheat or maize from their own farm. On these farms the use of mineral supplements was also restricted to common salt.

Figure 7 Supply of concentrate diets of various mixes on peri-urban large scale dairy farms studied in central Rift Valley, Oromia.

Data collection

Data collection was started from about one week postpartum. The utilization of available feed resources and daily milk yield of each selected farm was monitored and recorded every five days for 210 days. Daily milk yield of individual animal was monitored and recorded for both AM and PM using portable spring balance. The amount and type of feeds offered to individual animal was also weighed and recorded for each monitoring date. Both daily feed intake and milk yield for none collection days were estimated from average values of the preceding measurements. Accordingly the refusal of any feed type offered was weighed and recorded. The amount of daily nutrient intake over a given period was estimated by multiplying the nutrient content of the feeds (per kg dry matter) by the daily dry matter intake of the respective feed. Dry feed samples from each farm were collected fortnightly and bulked. They were thoroughly mixed, sub sampled and delivered to International Livestock Research Institute (ILRI) laboratory for chemical analysis. Milk sample was collected three times, at 4, 16 and 27 weeks of lactation period using 100 ml sampling bottle preserved with potassium dichromate and delivered the same day to the laboratory. On the large scale farms, any signs of estrus manifestation was visually observed and recorded by barn attendants and the veterinarian daily in the morning and after-noon. On the small scale farms the enumerators assigned for data recording visually observed and recorded any sign of estrus. In both cases mating practice was by artificial insemination (AI). However, on the small scale farms several skipped mating were observed due to shortage of AI facilities and/or unavailability of AI technicians. Gross margin analysis was used to compare the return on the management practices of the two farming systems (Pervaiz and Hendrik, 1989) for 305 days of lactation milk production. Information on costs of feed types and the values of fresh milk produced were obtained from the farmers. On the large scale farms where forage crops were produced costs of forages per kg dry matter yield was estimated from costs incurred for land preparation, seeds and seeding, weeding, electric power consumed for irrigation harvesting.

Chemical analysis

Feeds were analyzed for dry matter (DM), organic matter (OM) and crude protein (CP) using standard procedures of AOAC (1990). Neutral detergent fiber (NDF) was determined as described by Van Soest and Robertson (1985). The *in vitro* organic matter digestibility (IVOMD) was determined using the procedures described by Tilley and Terry (1963). Metabolizable energy (ME) content (MJ/kg DM) of feeds was estimated from *in vitro* organic matter digestibility (IVOMD (g/kg DM) x 0.016) as suggested by McDonald *et al*. (1988) and Barber *et al.* (1984). Metabolizable energy intake (MEI) was estimated by multiplying dry matter intake (DMI) of the feeds with the values of their respective energy concentration, i.e.; MEI (MJ/d) = DMI (kg/d) x ME (MJ/kg DM) according to Kearl (1982) and MAFF (1985). Calcium and sodium contents of the feeds were analyzed using atomic absorption spectrophotometers according to Perkins (1982), and phosphorus content was determined using auto analyzer of AOAC (1990). The daily crude protein (CP) and ME requirement for the animals was estimated based on actual average daily milk yield and fat content according to NRC (1989) recommendation. The composition of milk fat and protein were analyzed using Gerber method and formaldehyde titration respectively and total solid was determined by oven drying the milk sample according to O'Mahoney (1988).

Statistical analysis

Data on daily milk yield, milk compositions, postpartum reproductive efficiencies and nutrient intake were analyzed for farm scale, parity class and lactation period differences using the General Linear Model and multivariate analysis procedure of SPSS (1997). Mean differences between subjects under study were tested by pair-wise comparison and least significant difference (LSD) method. The relationships between intakes of feeds and nutrients from available feed resources and response variables were determined using Pearson correlation coefficient and simple regression analysis. The model used to analyze the effects of farm scale and parity classes on milk yield, reproductive traits and nutrient intake was:

$Y_{ij} = \mu + S_i + P_j + SP_{(ij)} + e_{(ijk)}$

Where, Y_{ijk} = the means of response variables measured.

μ = the overall mean

S_i = effect of i^{th} farm scale (i = 1, 2)

P_j = effect of j^{th} Parity class (j = 1, 2)

$SP_{(ij)}$ = interaction between farm scales and parity classes

$e_{(ijk)}$ = error term

The Model used to analyze effects of farm scale, parity classes and period on milk composition was:

$Y_{ijk} = \mu + S_i + P_j + T_k + e_{(ijk)}$

Where, Y_{ijk} = the means for milk composition

μ = the overall mean

S_i = effect of i^{th} farm scale (i = 1, 2)

Pj = effect of j^{th} Parity class (j = 1, 2)

T_k = effect of k^{th} period (k = 1, 2, 3)

$e_{(ijk)}$ = error term (assumed independently and normally distributed)

The model used to relate the quantity and quality of available feed resources to productive and reproductive traits measured was:

r = COVxy/VxVy

Where; x = Feed quality and quantity; Y = Response variables.

EXPERIMENT 2: Productive and reproductive responses of lactating cows fed hay and concentrate supplement with/without cottonseed cake and/or bole

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^{o}3'N latitude and 38^{o}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^{o}C and 22.1^{o}C respectively.

Animals and feeding management

Thirty-two pregnant Holstein Friesian cows with average body weight of 524±54 kg 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) (C), 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 substituted 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 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* hay dominantly composed of *Digitaria decombens, Eragirostis pilosa, Trifolium repens and Trifolium prantense* species. 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 NRC (2001).

Chemical analysis

Feeds were analyzed for dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE) and ash using standard procedures of AOAC (1990). Neutral detergent fiber (NDF) was determined using the method described by Van Soest and Robertson (1985). The *in vitro* organic matter digestibility (IVOMD) was determined using the procedures advanced by Tilley and Terry (1963). Metabolizable energy contents of the feeds was estimated from *in vitro* organic matter digestibility (IVOMD (g/kg DM) x 0.016) as suggested by McDonald *et al*. (1988) and Barber *et al*. (1984). Calcium (Ca), sodium (Na), potassium (K), magnesium (Mg) and manganese (Mn) contents of the feeds were analyzed using atomic absorption spectrophotometers according to Perkins (1982), and phosphorus (P) content was determined using auto-analyzer according to AOAC (1990). The compositions of milk fat and milk protein were analyzed using Gerber method and formaldehyde titration respectively and total solid was determined by oven drying the milk sample according to O'Mahoney (1988). Rumen DM degradability of the experimental diets was determined using three canulated cows with average body weight of 476± 23 kg per treatment. Two gm of three replicate samples milled through 2 mm mesh size were added to nylon bags of 6.5 x 14 cm and 41 μm pore size. Samples were incubated for each incubation time of 3, 6, 12, 24, and 48 for the dietary treatments and 3, 6, 12, 24, 48, 72 and 96 hours for the hay. The bags were introduced into the rumen by the method of sequential addition, with initial incubation of the last hour bags. After incubation the bags were washed under clean tap water thoroughly for about 30 minutes and then dried in a forced-air draught oven at 100^oC for 24 hours. The zero hour bags were not put in to the rumen but were subjected to the same washing and drying treatments. The rate and extent of dry matter disappearance was estimated using the equation of Orskov and McDonald (1979).

$P = a + b\ (1-e^{-ct})$

Where P = the potential dry matter disappearance

a = intercept (fast degradable fraction)

b = the potentially, but slowly degradable component

c = the rate of disappearance of b components

t = the time of incubation

e = natural log

Statistical analysis

Data were analyzed using general linear model (GLM) procedure of SAS (1999). Differences between treatment groups on intake of feeds and nutrients, milk yield and milk composition were evaluated using Duncan multiple range test. The model used to analyze the treatment effects on feeds and nutrient intake, milk yield and milk composition 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 AND DISCUSSION

Experiment 1: Comparative performances of Holstein Friesian cows under smallholder and large scale farmers' management in Central Rift Valley of Oromia, Ethiopia

Chemical compositions of available feed resources

Mean chemical compositions (% DM) of the available feed resources utilized in small and large scale farms are presented in Tables 3 and 4 respectively. Crude protein (CP) content of hay was higher (8.7% DM) in small scale farms than in large scale farms, which may be due to proper harvesting time and preservation methods. In large scale farms, the hay purchased may be harvested after being over matured and exposed to sun for longer time as opposed to that in small scale farms. Calcium, P and Na contents of hay were deficient for dairy cattle requirement in both small and large scale farms. Crop residues were used only in small scale farms (Table 3) and all types of crop residues were deficient in CP, Ca, P and Na contents, lower in IVOMD and higher in NDF contents.

Among the maize and native grass forages used in both farm scales, grass forage had sufficient Ca content in small scale farms (Table 3) while it was deficient in large sale farms (Table 4). Both forage types were deficient in P and Na contents in both farm scales. The variation in mineral compositions of grass forages may be due to variations in species compositions, soil types on which the forages were grown and stages of maturity at harvesting (Chesworth and Guerin, 1992).

Agro-industrial by-products and non-conventional feed resource of homemade liquor residue (atala) were used only in small scale farms (Table 3). Nougseed cake and linseed cake were sufficient in Ca and P content but deficient in Na contents and this is consistent with the reports of Solomon (1992) who reported that locally produced oil seed cakes were deficient in Ca and Na contents, but sufficient in P, K and Mg contents. Cottonseed cake and wheat bran were deficient in Ca and Na contents but sufficient in P content. Mixed concentrate was sufficient in CP, ME and P contents in both farm scales. But it was deficient in Ca and Na in small scale farms, while in large scale farms it was deficient in Ca but sufficient in Na content. The low Ca and Na content of concentrate diets in small scale farms was due the fact that they used mainly the ingredients of wheat bran and nougseed cake or linseed cake which are both deficient in the these mineral elements. However, large scale farms used reasonably sufficient common salt to supply sufficient Na but did not consider supplements for Ca sources such as limestone. Some of the small scale farmers used cereal crop residues after soaking them with home-made brewers' grain by-products. It was observed that soaking tef and wheat straws with brewer's grain by product substantially increased the CP, ME, Ca compositions and IVOMD of the feeds (Table 3).

Table 3 Mean chemical compositions of available feed resources for Holstein Friesian cows in small-scale farms of central Rift Valley, Oromia.

Feed types	DM	%DM								
		CP	ME (MJ/kg)	NDF	EE	Ash	IVOMD	Ca	P	Na
Hay	91	8.68	7.12	75.34	1.44	10.33	46.54	0.40	0.18	0.011
Wheat straw	92	2.56	5.66	81.58	0.93	8.21	36.33	0.09	0.05	0.008
Wheat straw*	62	13.10	10.4	59.00	8.4	6.5	65.10	0.40	0.40	0.22
Maize stover	91	5.63	8.74	81.24	0.69	8.21	55.30	0.35	0.10	0.02
Tef (*Eragrostis abyssinica*) straw	92	3.75	6.04	83.49	1.13	6.64	38.63	0.17	0.08	0.008
Tef straw*	73	12.70	9.70	59.90	5.10	6.10	60.90	0.33	0.40	0.03
Haricot bean straw	91	5.19	6.66	70.95	0.65	8.06	42.50	0.18	0.05	0.008
Maize forage	21	10.38	8.90	72.49	1.65	9.22	55.85	0.23	0.15	0.02
Grass forage	13	13.50	9.34	75.45	1.14	12.22	54.54	0.51	0.31	0.02
Nougseed cake	91	29.75	10.31	39.43	6.22	10.91	58.07	0.69	0.99	0.003
Linseed cake	90	28.81	13.40	37.78	8.07	8.47	68.40	0.51	0.50	0.02
Cottonseed cake	90	22.31	12.06	48.73	6.63	5.56	47.50	0.19	0.74	0.008
Wheat bran	88	17.06	11.63	38.44	4.55	4.36	72.44	0.11	1.00	0.005
Molasses	74	3.31	12.67	-	-	18.94	99.69	1.80	0.10	0.26
Atala[c]	13	21.40	11.00	57.22	-	4.02	69.00	0.61	0.59	0.004
Mixed concentrate	89	22.06	10.40	36.74	5.87	6.12	64.91	0.28	1.05	0.003

[c] Home-made brewers grain residue.
* Feed soaked in homemade brewer's grain residues.

Table 4 Chemical compositions of available feed resources for Holstein Friesian cows in large scale farms of central Rift Valley, Oromia.

Feed types	DM	%DM								
		CP	ME (MJ/kg)	NDF	EE	Ash	IVOMD	Ca	P	Na
Hay	92	4.75	5.91	76.90	1.19	8.50	38.94	0.30	0.15	0.054
Alfalfa forage	35	15.50	9.62	56.72	1.91	11.80	53.89	1.04	0.32	0.023
Elephant grass forage	15	13.10	9.02	68.00	1.94	17.06	50.33	0.21	0.28	0.01
Maize forage	35	6.25	9.90	62.32	1.32	9.22	62.24	0.23	0.33	0.002
Grass forage	13	9.13	6.70	75.85	1.37	9.32	44.96	0.43	0.29	0.011
Molasses	74	3.50	15.90	-	5.9	18.84	99.69	1.8	0.10	0.26
Mixed concentrate	89	20.16	10.7	36.62	4.66	7.91	66.56	0.36	1.03	0.42

Feeds and nutrient intake

Significant differences were observed between the large and small scale farms in daily intake of DM, CP, ether extract (EE), P ($p<0.001$), ME, and Na ($p<0.01$) (Table 5). Animals on the large scale farms had higher intake of DM (39%), CP (38%), ME (23%), P (60%) and Na (33%) than those on small scale farms. The intakes of CP for the small and large scale farms was 27 and 28% higher respectively than the estimated requirement (Table 5) level and that of ME for small and large scale farms was 10 and 6% respectively. Dietary calcium intake (%DMI) for animals in small scale farms was below the recommended range (0.43 to 0.77 %DMI) of NRC (1989) while that of large scale farms was marginal. The intake of P was within the recommended marginal level of 0.33 - 0.48% of DMI for small scale farms while it was sufficiently higher for animals on the large scale farms.

Table 5 Mean daily feeds and nutrient intake of Holstein Friesian cows under two different farmers' management scales in central Rift Valley.

Daily nutrient intake	Farm scales			
	Small	Large		
Number of animals	14	14	SE	p
Total DM intake (kg/d)	11.4	15.8	0.47	***
Roughage	4.9	6.3	0.33	**
Supplement	6.5	9.5	0.44	***
Total CP intake (g/d)	1704	2343	123..00	***
Roughage	259	477	45.85	**
Supplement	1445	1886	104.63	**
CP intake (%DMI)	14.5	15.4	0.59	NS
Total ME intake (MJ/d)	115	141	5.66	**
Roughage	34	41	2.26	*
Supplement	81	100	6.31	*
NDF intake (%DMI)	45.21	49.90	2.35	NS
EE intake (%DMI)	4.2	3.4	0.14	***
Roughage NDF (% total NDF)	71	53	2.26	***
Ca intake (%DMI)	0.40	0.43	0.02	NS
P intake (%DMI)	0.48	0.77	0.04	***
Na intake (%DMI)	0.03	0.26	0.001	**
CP requirement (g/d/head)	1238	1696	89.00	-
ME requirement (MJ/d/head)	103	133	3.78	-

***=p<0.001; **=p<0.01; *=p<0.05.

[x, y] CP and ME Requirements were estimated based on the actual milk yield (kg/d) and body weights of animals (NRC, 1989).

The ratios of Ca: P was 0.8:1 and 0.6:1 in small scale and large scale farms respectively, while the recommended optimum level was 1: to 2:1 (McDowell, 1983). Dietary sodium intake was critically below the required level of 0.18% (NRC 1988) in small scale farms, but sufficiently high in large scale farms. Preserved crop residues of different types (maize stover, tef straw, wheat straw and haricot bean) were the major basal feed base for small scale farms in this study. These crop residues were low in digestible matter, nitrogen and true protein content which may limit the intake of DM and other nutrients. Chenost and Sansoucy (1991); Chesworth and Guérin (1992) reported that voluntary feed intake of ruminants essentially depends on the rate of degradation of its digestible matter. About 43% of the total DM consumed by animals on the small scale farms was roughage feed as compared to 38.6% on the large scale farms. Similarly about 71% of NDF intake of animals on the small scale farms was roughage feeds as compared to 53% on the large scale farms. The utilization of agro-industrial by-products such as nougseed cake (*Guizota abyssinica*), linseed cake, cotton seed cake and wheat bran was minimal (7.76% DMI). A home-made brewer's grain by products (39% DMI) mixed with crop residues or alone was also used. Mixed concentrate in the daily dietary DM intake of animals in small scale farms was only 9.6%. Since the potential intake of forage is inversely related to its NDF content, the DM intake and consequently that of other nutrients were limited for animals in small scale farms. Feeds and nutrient intake were not significantly ($p>0.05$) different between parity classes (Table 7).

Milk yield, milk composition and reproductive efficiency

The mean daily milk yield, milk composition and postpartum reproductive efficiencies of Holstein Friesian cows on large and small scale farms are presented in Table 6. Difference in actual and fat corrected (FC) daily milk yield was highly significant ($p<0.001$) between the two farm scales. There were higher daily milk yield and FC milk yield (15.8 and 14.7 kg respectively) on the large scale farms than on small scale farms (11.5 and 11.1 kg respectively). The higher milk yield of animals on large scale farms may be attributed to higher intake of DM, CP, ME, Ca and P relative to the small scale farms. With high technological inputs in terms of feeding management and health care milk production per cow is extremely very high than with low inputs (Leng, 1991). The utilization of conserved hay, green forages and mixed concentrate on large scale farms were about 26.6%, 12% and 59% of daily DM intake respectively as compared to only 6.4, 5.4 and 9.6% respectively on small scale farms. This also reflects that the productivity of ruminants is influenced primarily by quantity and quality of feed intake (Preston and Leng, 1987).

The quantity of CP and ME may not be the limiting factors for low performances of the animals under this study. Possible reasons for the low milk yield performances of animals in small scale farms may be due to poor nutritional qualities of crop residues used (about 36.4% of daily DM intake), the CP intake from home-made liquor residues which was about 39% of daily DM intake and provided about 76% of the total CP intake may be heat damaged during the long time boiling for alcohol distillation. Therefore, its CP may be unusable or poorly digested in the lower digestive tract as well as in the rumen. This may resulted in too low ammonia levels in the rumen which can not meet the requirement for efficient growth of rumen micro-organisms (Perston and Leng, 1987). Sources of supplemental CP are an important factor to influence the response of animals, due to their variation in type and levels of essential amino acid (EAA) contents (Christensen *et al.,* 1993).

Table 6 Mean daily milk yield, milk compositions and reproductive efficiency of Holstein Friesian cows under two farm scales.

Parameters	Farm scales		SE	p
	Small	Large		
Number of animals	14	14		
Milk yield (kg)	11.5	15.8	0.73	***
FC milk yield (kg)[a]	11.1	14.7	0.67	***
Fat (%)	3.8	3.6	0.17	NS
Protein (%)	2.9	2.8	0.08	NS
Total solid (%)	11.22	11.30	0.16	NS
Calving to first sign of estrus (d)	96	115	14.60	NS
Days open	171	148	23.50	NS
Services/conception	1.6	2.1	0.24	NS

***=p<0.001.
[a]FC = fat corrected.

In addition, the minimal and inconsistent use of protein sources from mixed concentrate and agro-industrial by-products by small scale farmers may result in lower nutrient intake and consequently low productivity of the animals. On both small and large farm scales the ratio of Ca: P was observed to be very low (0.83:1 and 0.56:1 respectively). McDowell *et al.* (1983) reported that with dietary ratios below 1:1 and over 7:1 growth and feed efficiency decreased significantly. Simon (2005) in Tanzania reported that, there were high milk yield in large scale farms compared to smallholder farms. Differences in milk production between the two management systems were attributed mainly to the level of management. Like small scale farmers in other developing countries (Leng, 1991), smallholder farmers in this study could not be able to select quality basal diet, than using whatever was available at no or low cost.

Lactation curve over weeks for animals in the two scales of management and parity classes are comparatively presented in Figures 8 and 9. On the large scale farms, there was fast and longer increases of milk yield up to the peak yield of 17.8 kg at week 3, but sharply declined thereafter (Figure 8). The trend of increase on the small scale farms was relatively slow and short. The peak yield of 13.1 kg was attained at week 4 and thereafter immediately declined on small scale farms. Although the differences were not significant ($p>0.05$) animals in advanced parities (3-6) on both farm scales performed better than those in early (1-2) parities (Figure 9). On large scale farms animals in early parity (1-2) attained peak yield of 17.9 kg/d at week 4 and the trend of decline was slower than for those in advanced parities (3-6). But animals in advanced parities attained peak yield of 17.8 kg/d at week 3 and the trend of decline was relatively faster than that of their counterparts. The trend of increase was slow and shorter for animals in both parities in small scale farms. On the large scale farms milk yield of animals in the two parity classes was not far apart as that of animals on small scale farms (Figure 8). This could be due the fact that 5 out of 7 animals in early parity classes (1-2) in large scale farms were in their second parities while only 3 out of 7 animals in the same parity class were in their second parities in small scale farms. Animals in advanced parities attained peak yield at week 7 and the trend of decline was also slower relative to those in early parities, which attained very short peak yield at week 4. Milk composition was not significantly ($p>0.05$) differed among the two farm scales and parities, (Tables 6 and 7).

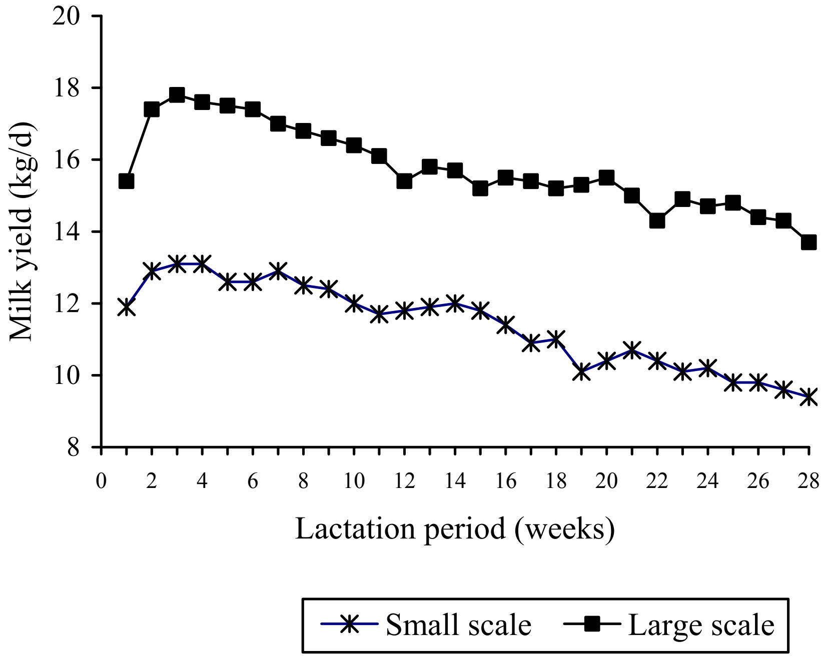


Figure 8 Mean daily milk yield of cows in two different farm scales during 28 weeks of lactation.

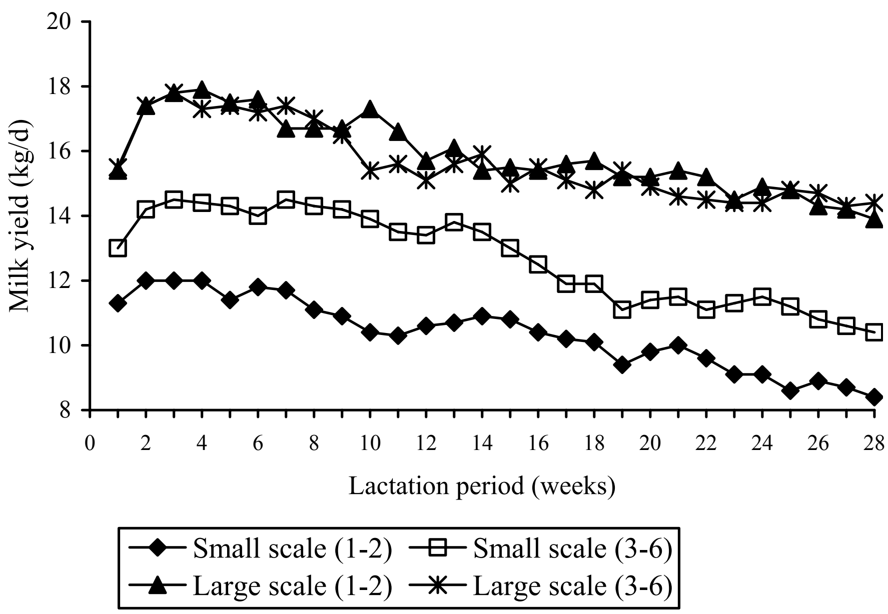


Figure 9 Mean daily milk yield of cows in two different farm scales and parity classes of 1-2 and 3-6 over 28 weeks of lactation.

Table 7 Mean daily milk yield and compositions, nutrient intake and reproductive efficiency of Holstein Friesian cows under two parity classes.

Parameters	Parity classes		SE	p
	1-2	3-6		
Number of animals	14	14		
Milk yield (kg/d)	13.30	13.90	0.73	NS
FC milk yield (kg/d)	12.60	13.20	0.67	NS
Fat (%)	3.70	3.60	0.17	NS
Protein (%)	2.78	2.82	0.08	NS
Total solid (%)	11.25	11.27	0.17	NS
Dry matter intake (kg/d)	13.70	13.50	0.73	NS
Crude protein intake (g/d)	2092.00	1956.00	123.19	NS
ME intake (MJ/d)	130	126	5.66	**
Calving to first sign of estrus (d)	105	106	14.50	NS
Days open	163	156	23.50	NS
Services/conception	1.8	1.7	0.19	NS

**=p<0.01; NS=not significant.

There was significant overall effect of period on the content of milk protein ($p<0.001$) and total solid ($p<0.01$) (Table 8) as well as on both farm scales. But milk fat content was not differed ($p>0.05$) between periods of lactation. Higher milk protein content was observed in week 27 of lactation. This may be partly due to increased dietary CP concentration during week 27. Dietary concentrations of crude protein during the weeks 4, 16 and 27 were 13.6, 14.9 and 15.6% respectively. There was an increase in the protein content of milk as crude protein concentration in the diet increased (Holter *et al.*, 1982). Macleod *et al.* (1983) also observed high responses of milk protein content to increased dietary CP concentration on low energy diets, which was consistent with this result in which calculated dietary energy intake (MJ/d) in weeks 4, 16 and 27, were 142.77, 122.86 and 118.07 respectively. In addition, stage of lactation of animals also had significant influence on compositions of milk in dairy cows. DePeters and Cant (1992) reported that following calving up to weeks 5 to 10 milk protein content decreases, and there after, gradually increases through the end of lactation.

Table 8 Effect of lactation period on milk composition of Holstein Friesian cows under two farm scales.

Farm Scales	Compositions	Lactation periods			SE	p
		Week 4	Week 16	Week 27		
	No of animals	14	14	14		
Small	Fat (%)	3.98	3.46	4.01	0.31	NS
	Protein (%)	2.77[b]	2.36[b]	3.43[a]	0.16	***
	Total solid (%)	10.66[b]	11.20[ab]	12.17[a]	0.38	**
Large	Fat (%)	3.48	3.66	3.58	0.15	NS
	Protein (%)	2.34[b]	2.47[b]	3.60[a]	0.13	***
	Total solid (%)	10.71[b]	11.76[a]	11.39[ab]	0.26	**
Overall	Fat (%)	3.71	3.56	3.79	0.11	NS
	Protein (%)	2.55[b]	2.42[b]	3.51[a]	0.07	***
	Total solid (%)	10.64[b]	11.48[ab]	11.78[a]	0.15	**

***=p<0.001; **=p<0.01.
[a, b,] means with the different superscripts in the same row are significantly different (p<0.05).

The days from calving to first estrus (CFE), days open (DO) and the number of services per conception (S/C) was not significantly (p>0.05) different between the farm scales (Table 6) and parity classes (Table 7). But the value of DO (171d) on small scale farms was longer than on the large scale farms (148 d). This is due to lack of regular AI services and several skipped matting observed. The days to first estrus (115d) and SPC (2.1) were higher on the large scale farms than on the smallholder farms, (96 and 1.6 respectively), which may be due to poor heat detection practices. Since the number of animals on small scale farms was very few, farmers could be able to closely observe estrus manifestation of their animals than the large scale farms where there was relatively large number of animals and could not be easy to closely observe estrus manifestation of individual animal.

Relationship of nutrients intake with productive and reproductive performances.

Correlation coefficients of available nutrients intake with productive and reproductive parameters of dairy cows under on-farm small and large scale farmers management systems is presented in Table 9. There was positive and significant linear correlation of dry matter intake with daily actual milk yield (r=0.66; p=0.001) and FC milk yield (r=0.60; p=0.001) fitting the regression equations Y=1.35 + 0.89x and Y= 3.35 + 0.69x respectively (Figures 10a and b). Dry matter intake is a major factor limiting milk production of dairy cows, particularly in early lactation. Inadequate dry matter intake results in body weight lose, reduced milk production or both, because their nutrient requirements particularly energy supply cannot be met from the intake (Kertz *et al*., 1991). Oba and Allen (1999) reported that milk yield and 4% FC milk yield were linearly and positively related to dry matter intake, which in turn was associated with its NDF digestibility.

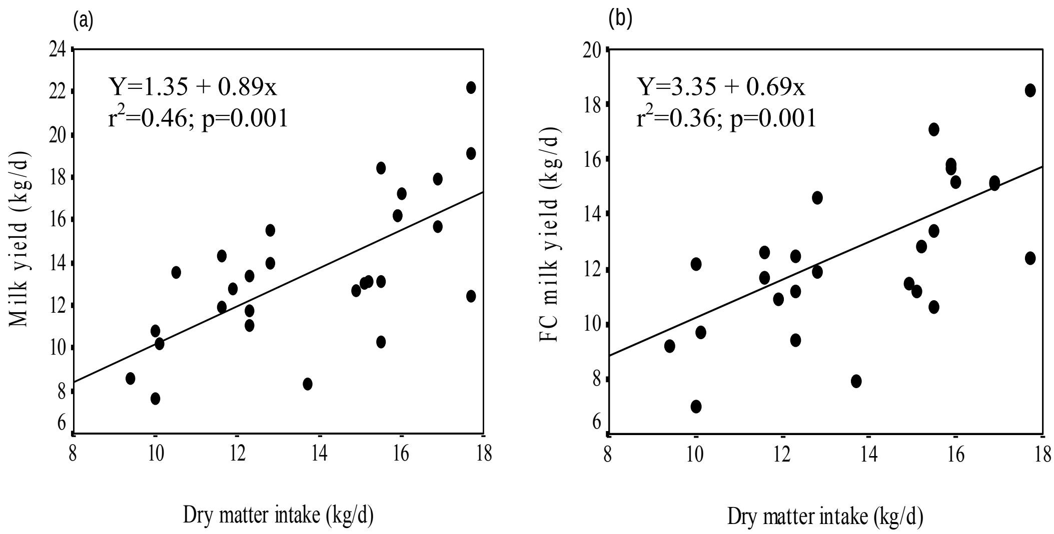


Figure 10 Regressions of daily (a) actual and (b) FC milk yield on dry matter intake of dairy cows under farmers' management systems.

Table 9 Correlation coefficients of dry matter and nutrients intake with milk yield, milk components and reproductive parameters.

	Milk yield	**FC milk yield**	**Fat (%)**	**Fat yield**	**Protein (%)**	**Protein yield**	**Total solid (%)**	**CFE**	**Days open**	**SPC**
DM intake	0.66	0.60	-0.28	0.51	-0.29	0.61	-0.16	0.22	-0.03	0.38
p=	***	***	NS	**	NS	***	NS	NS	NS	*
CP intake	0.65	0.60	-0.14	0.54	-0.20	0.60	-0.03	0.22	0.09	0.54
p=	***	***	NS	**	NS	***	NS	NS	NS	**
CP (% DMI)	0.43	0.35	-0.06	0.32	-0.14	0.35	-0.01	0.32	0.11	0.35
p=	*	*	NS	NS	NS	NS	NS	NS	NS	NS
ME (MJ)	0.58	0.50	-0.22	0.43	-0.21	0.52	-0.02	0.07	0.08	0.55
p=	***	**	NS	*	NS	**	NS	NS	NS	**
NDF (% DMI)	0.20	0.26	0.08	0.28	0.04	0.25	0.01	0.23	0.00	-0.06
p=	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EE (% DMI)	-0.43	-0.48	0.02	-0.46	-0.18	-0.43	-0.02	-0.17	0.04	-0.13
p=	*	*	NS	*	NS	*	NS	NS	NS	NS
Calcium (% DMI)	0.40	0.27	-0.34	0.16	-0.26	0.27	-0.12	0.13	0.14	0.42
p=	*	NS	NS	NS	NS	NS	NS	NS	NS	*
Phosphorus (% DMI)	0.68	0.65	-0.11	0.61	-0.22	0.61	0.08	0.34	0.00	0.46
p=	***	***	NS	***	NS	***	NS	NS	NS	*
Sodium (% DMI)	0.22	0.24	0.02	0.24	-0.18	0.11	0.11	-0.17	-0.37	-0.12
p=	NS	NS	NS	NS	NS	NS	NS	NS	*	NS

There was negative and non significant correlation of dry matter intake with milk fat (r= -0.28; p=0.15), milk protein (r= -0.29; p=0.13) and milk total solid (r = -0.16; p=0.42) contents, but significant and positive linear correlation was observed with milk fat yield (r= 0.51; p=0.01), and protein yield (r=0.61; p=0.001) fitting the regression equations Y=0.18 + 0.02x and Y= 0.05 + 0.02x respectively (Figures 11a and b). Components of milk are subject to manipulation through diets. Although, each cow has a certain genetic capability to produce milk, her ability to achieve this potential depends on the extent to which the diet supplies the necessary precursors for the synthesis of milk components (Kennelly, 1993). Dry matter intake was negatively and non-significantly correlated with milk total solid content. Dietary dry matter intake had no significant correlation with days from calving to first observed estrus and days open.

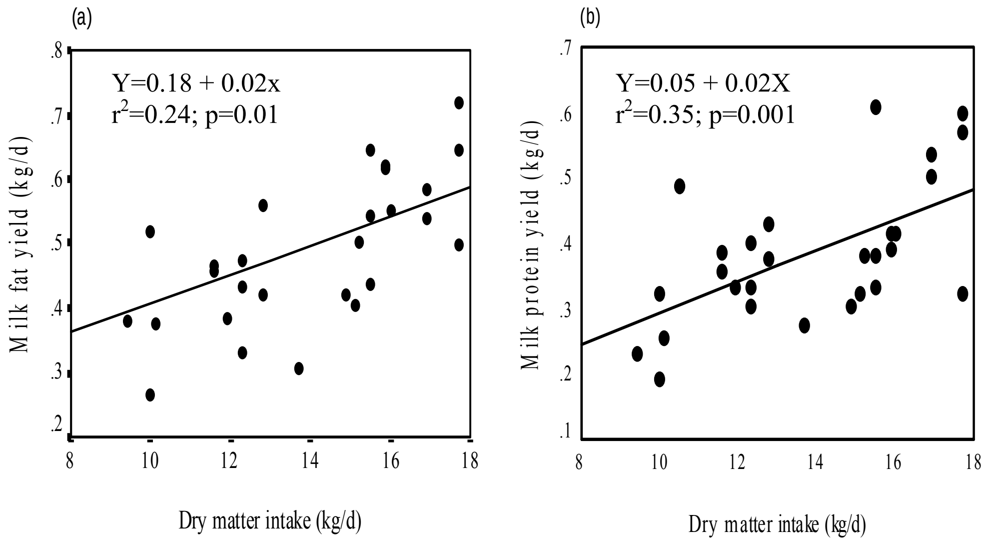


Figure 11 Regressions of (a) milk fat yield and (b) milk protein yield on dry matter intake of dairy cows under farmers' management system.

Daily intake of dietary crude protein had positive and significant linear correlations with daily actual milk yield (r=0.66; p=0.0.001) and 4% FC milk yield (r=0.63; p=0.001) fitting the regression equations Y=5.2 + 0.004x and Y= 5.85 + 0.003x respectively (Figures 12a and b). Dietary crude protein intake had positive and significant linear correlations with milk fat yield (r=0.54; p= 0.003) and protein yield (r=0.60; p=0.001) (Figures 13a and b), but had negative and non-significant correlations with milk fat (r=-0.14; p=0.49), protein (r=-0.20; p=32) and total solid (r=-0.03; p=0.90) percentages, and this agrees the reports of DePeters and Cant (1992) in which negative partial correlation (r= -0.17) was observed between protein intake and protein content of milk.

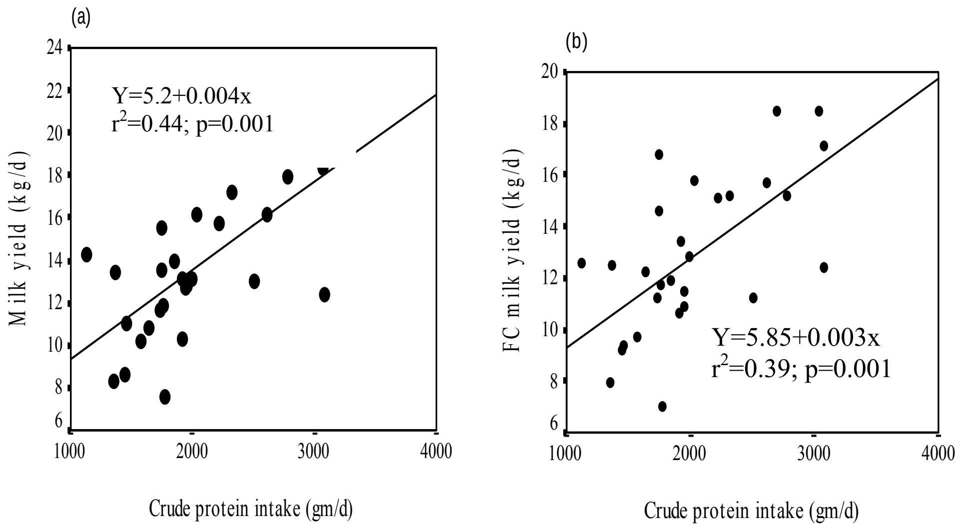


Figure 12 Regressions of (a) daily actual milk yield and (b) 4% FC milk yield on dietary crude protein intake (gm/d) of dairy cows under farmers' management system.

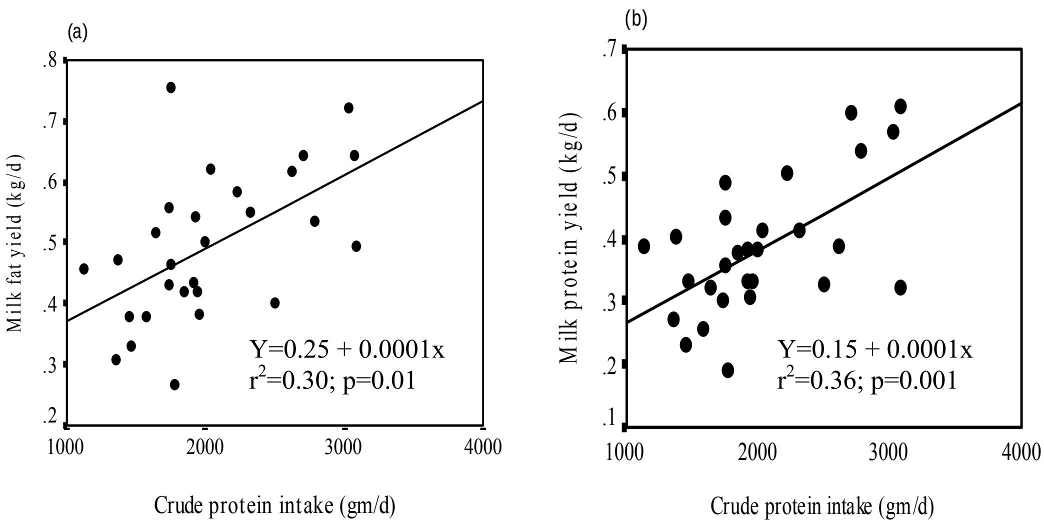


Figure 13 Regressions of (a) daily milk fat yield and (b) milk protein yield on dietary crude protein intake of dairy cows under farmers' management systems.

Similarly, dietary concentration of crude protein (%DMI) had positive linear correlations with daily actual milk yield (r=0.43; p=0.02) and 4% FC milk yield (r=0.35; p=0.06) (Figures 14a and b). There was positive and non-significant correlation of crude protein concentration with milk fat yield (r=0.32; p=0.09) and protein yield (r=0.35; p=0.07). These results were consistent with the reports of Roffler *et al.* (1978) and Cunningham *et al.* (1996) in which yields of milk, milk fat and milk protein were positively increased as dietary crude protein increased. The amount and type of dietary protein can also influence the content and yield of milk protein (DePeters and Cant, 1992). Feeding protein deficient diet can slightly reduce milk protein content and can reduce milk protein yield, but feeding of excess protein cannot increase the protein content of milk beyond a cow's genetic capabilities (Schingoethe, 1996). The correlation of crude protein intake and dietary crude protein concentrations with days from calving to first estrus and days open were not significant (p>0.05); however, there was significant quadratic correlation of dietary crude protein intake with number of services per conception (r=.0.54; p=0.01).

Dietary concentration of crude protein had non-significant quadratic correlations with the days from calving to first estrus (r=0.32; p=0.09), days open (r=0.11; p=0.59) (Figures 15a and b) and the number of services per conception (r=0.35; p=0.07). The days from calving to first observed estrus, days open and the number of services required per conception tend to increase with the increased total CP intake of above 2000 gm/d or when dietary CP concentration exceeds 16 percent and this agrees with the reports of Jordan and Swanson (1979) in which feeding higher crude protein increased the number of days open in high producing dairy cows. Increased CP concentration from 12.7 to 19.3% had negative influence on reproductive performances. The days open and services per conception for the three groups of animals fed diets with 12.7, 16.3 and 19.3% CP were 69, 96 and 106; and 1.47, 1.87 and 2.47 respectively. Kaim *et al.* (1983) also reported that there was lower (43%) conception rate of dairy cows fed high protein diet versus those fed low protein diet (57%). Thus, feeding excess protein than requirement appears to be wasteful in that it is expensive and also impairs reproductive performances without increasing milk production.

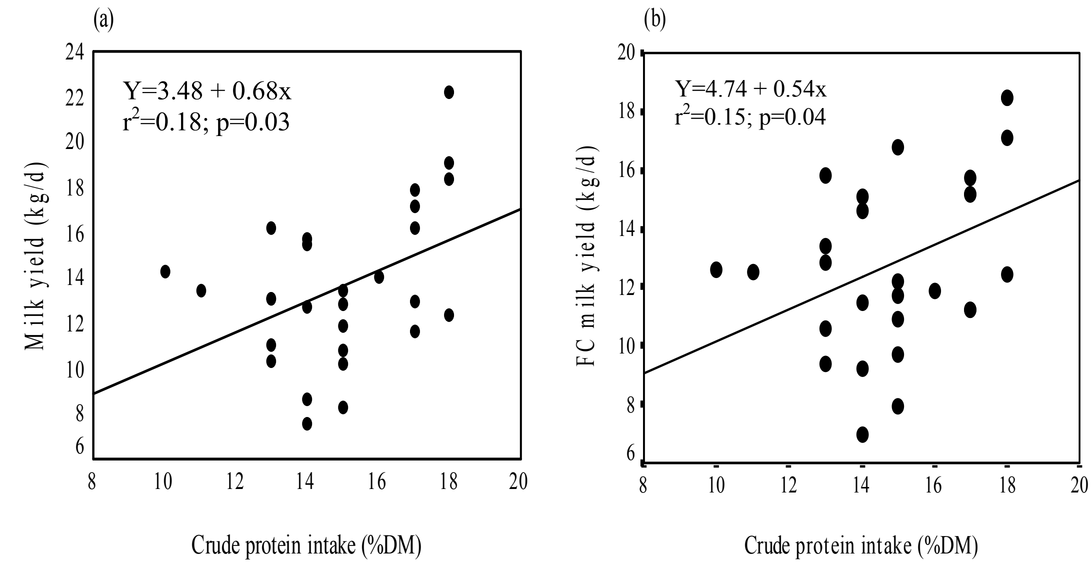


Figure 14 Regressions of (a) daily actual milk yield and (b) 4% FC milk yield on dietary crude protein concentration (%DMI) of dairy cows under farmers' management system.

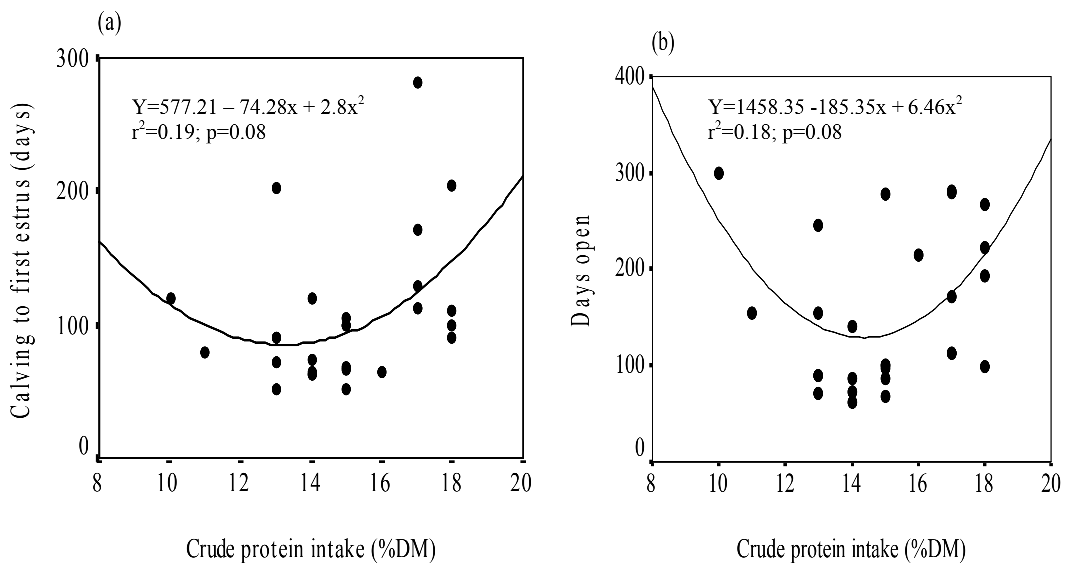


Figure 15 Regressions of (a) days from calving to first estrus and (b) days open on dietary crude protein concentration (%DMI) of dairy cows under farmers' management system.

There was positive and significant linear correlation of dietary ME intake with daily actual milk yield (r=0.58; p=0.001) and FC milk yield (r=0.50; p=0.01), fitting the regression equations Y=2.88 +0.08x and Y=4.44 +0.07x respectively (Figures 16a and b). The intake of ME had also positive and significant linear correlations with milk fat yield (r=0.43; p=0.02) and protein yield (r=0.52; p=0.01) (Figures 17a and b). There was negative and non-significant linear correlation of ME intakes with milk fat (r= -0.22; p=0.25), protein (r= -0.21; p=0.28) and total solid (r=-0.02; p=0.94) contents. This result partly agrees with the findings of Schingoethe (1996) in which both the amount and concentrations of ME were positively related with either milk protein yield (r=0.89 and 0.65) or protein content (r=0.42 and 0.31), but inconsistent with the reports of Emery (1978) which revealed that milk protein content increased 0.6 gm/kg for each mega joule increase of net energy intake (r=0.42). Broderick (2003) reported that increasing dietary energy density and NSC linearly increased body weight gain and yields of milk and all milk components except milk fat which was linearly declined with increased energy intake.

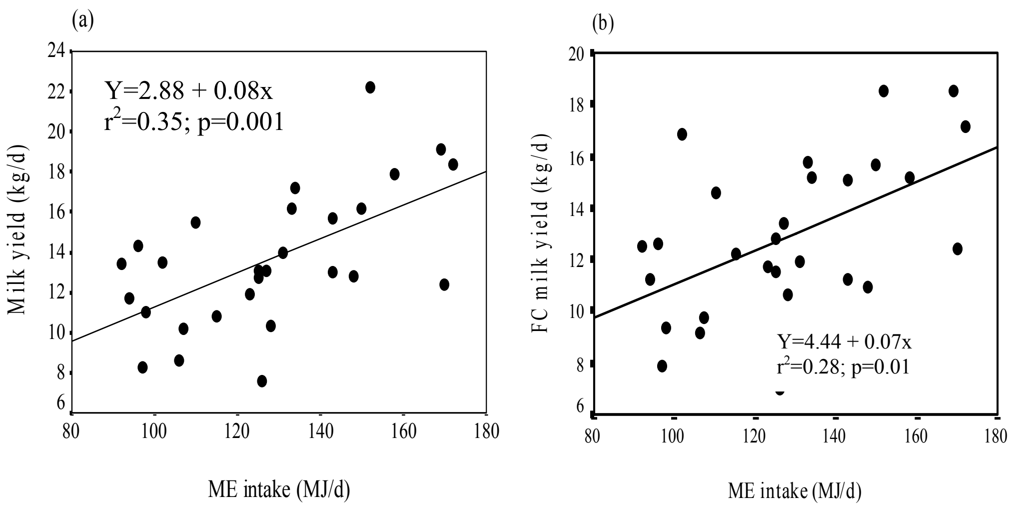


Figure 16 Regressions of (a) daily actual milk yield and (b) FC milk yield on dietary ME intake (MJ/d) of dairy cows under farmers' management system.

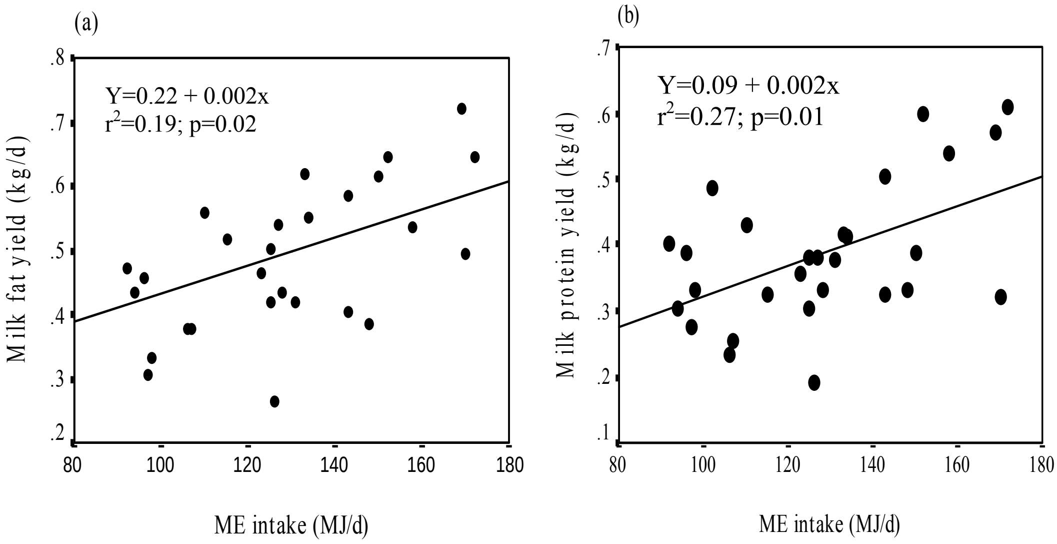


Figure 17 Regressions of (a) daily milk fat yield and (b) protein yield on dietary ME intake (MJ/d) of dairy cows under farmers' management systems.

Complex interrelationships exist between dietary protein and energy and the amounts of protein that will be utilized by the dairy cows (Rotz *et al.,* 1999). Dietary protein supplies metabolizable protein by providing both RDP that is utilized for microbial protein formation and RUP that is digested directly by the cow. High energy diets stimulate microbial protein synthesis (Cadoringa and Satter, 1993). Dietary ME intake had no significant correlations with days from calving to first estrus and days open.

There was non-significant quadratic correlation of dietary NDF concentration (%DMI) with daily actual milk yield (r = 0.39; p=0.12) and significant quadratic correlation with FC milk yield (r= 0.46; p=0.05), fitting the regression equations $Y = -15.68 + 1.2x - 0.01x^2$ and $Y = -17.04 + 1.2x - 0.01x^2$ (Figure 18a and b). Intake of NDF was not correlated with milk fat and milk protein contents. But there was positive and non-significant linear correlations with milk fat yield (r=028; p=0.16) and milk protein yield (r=0.25; p=0.19) (Figures 19a and b). The weak and non-significant correlation of NDF intake with milk yield an all milk components may be due to poor digestibility of dietary fiber. The yields of milk, milk fat and milk protein tend to decline with NDF concentrations of above 55% (dry matter basis).

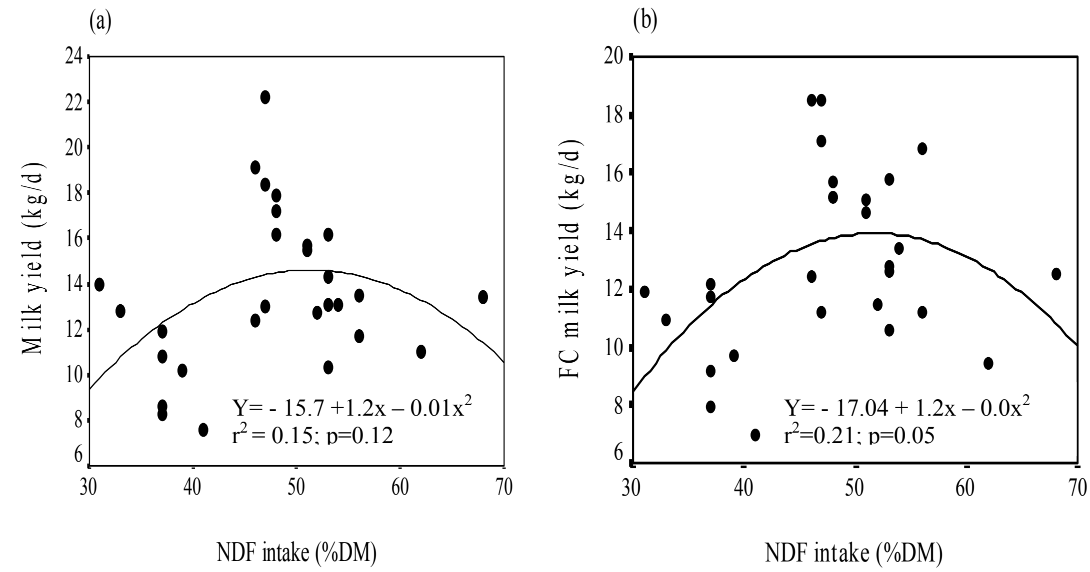


Figure 18 Regressions of (a) daily actual milk yield and (b) FC milk yield on dietary NDF intake (%DMI) of dairy cows in on-farm farmers' management. systems.

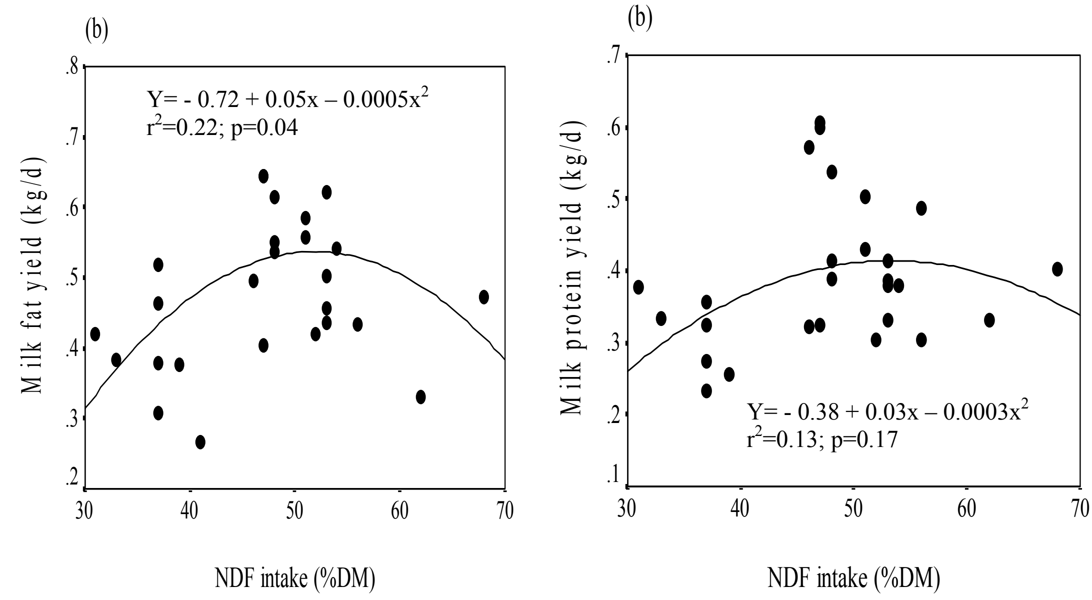
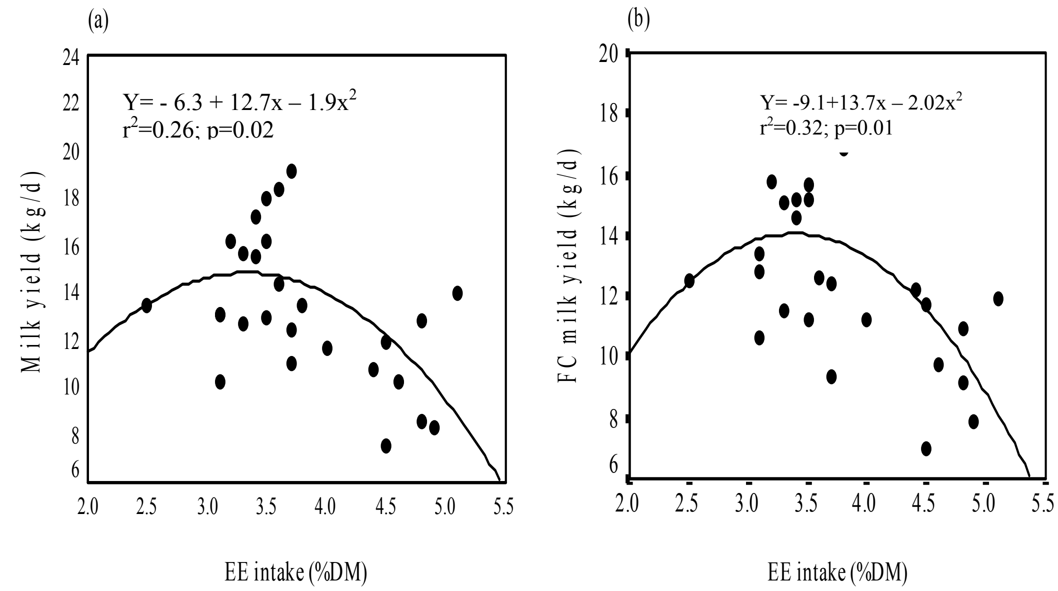


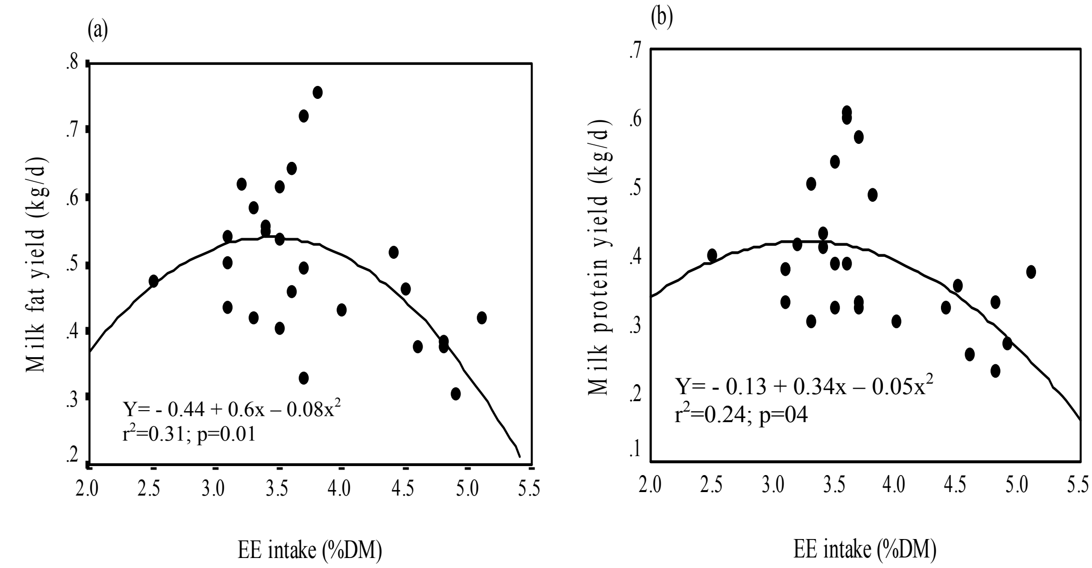
Figure 19 Regressions of (a) daily milk fat yield and (b) milk protein yield on dietary NDF intake (%DMI) of dairy cows in on-farm farmers' management systems.

Although dietary fiber has significant role in stimulating rumination and saliva secretion, its digestibility and rate of passage from the reticulo-rumen affects dry matter intake and consequently the productivity of animals. Mertens (1994) reported that at high NDF concentration in the diets rumen fill limits dry matter intake. At any particular NDF concentration in the diet, a considerable range in dry matter intake was observed, suggesting the sources of NDF in the diet as affected by particle size and digestibility. The concentration of NDF in feeds or diets is negatively correlated with energy concentration. The proportion of cellulose, hemi-cellulose and lignin in NDF fraction affect its digestibility (NRC, 2001; Oba and Allen, 1999).

Dietary concentration of EE had significant quadratic correlations with daily actual milk yield (r=0.51; p=0.02), FC milk yield (r=0.57; p=0.01) (Figures 20a and b), milk fat yield (r=0.55; p=0.01) and milk protein yield (r=0.49; p=0.04) (Figure 21a and b). There was no significant correlation of EE intake with milk fat and protein contents. With dietary concentration of more than 3.5% EE the yields of milk, milk fat and milk protein tend to decline and this is consistent with the findings of Jenkins (1994) in which milk yield responses to supplemental fat was curvilinear and the response diminished as supplemental fat in the diet increased. Supplemental fat has increased milk yield in many studies; however, the responses have been variable due to depression in feed intake and consequently total energy intake by the cow may not be increased. Feeding high concentration of dietary fat can result in reduced dry matter intake, and reduction in dry matter intake can negate part or all advantages of using fat to increase dietary energy density and can limit milk production responses (Schauff and Clark, 1992). Optimal amount of fat to be included in dairy cattle diets depend on factors such as type of fat, feeds making up the basal diet, stage of lactation, environment and level of milk production. Several studies have suggested that unsaturated fatty acids are more likely to depress feed intake and ruminal fiber digestion than saturated fatty acids (Drackley *et al.*, 1992; Christensen *et al.,* 1994; Firkins and Eastridge, 1994). Mechanisms by which fat reduces feed intake are not known. Potential factors were recently reviewed (Allen, 2000) and include effects on gut motility, acceptability of diets supplemented with fat, release of gut hormones and oxidation of fat by the liver. Sanchez *et al.* (1994b) also further speculated that insufficient metabolizable protein may account for feed intake depression when feeding fat.



<u>Figure 20</u> Regressions of (a) daily actual milk yield and (b) FC milk yield on dietary EE intake (%DMI) of dairy cows in on-farm farmers' management systems.



<u>Figure 21</u> Regressions of (a) daily milk fat yield and (b) milk protein yield on dietary EE intake (%DMI) of dairy cows in on-farm farmers' management systems.

The influence of supplemental fat on milk fat percentage is variable and depends on fat compositions and the amount fed (Sutton, 1989). Feeding supplemental fat decreases milk protein percentage. Although, milk protein percentage is usually depressed with supplemental fat, total protein production usually remains constant or increased (Wu and Hubber, 1994). In some cases in which milk protein production decreased, milk production also was decreased.

There was non-significant quadratic correlation of dietary EE concentration (%DMI) with days from calving to first observed estrus (r=0.44; p=0.07), days open (r=0.21; p=0.56) (Figures 22a and b) and number of services required per conception (r=0.33; p=0.25). In this study at 3.5% of EE concentration where higher milk yield response was observed, reproductive efficiencies were reduced by increased interval days from calving to first estrus and days open, but these traits were tended to be improved as the concentration of EE increased above 4.5% (DMI). Staples *et al.* (1989) reported that supplemental fat positively influence reproductive performances of dairy cows by increasing conception rate.

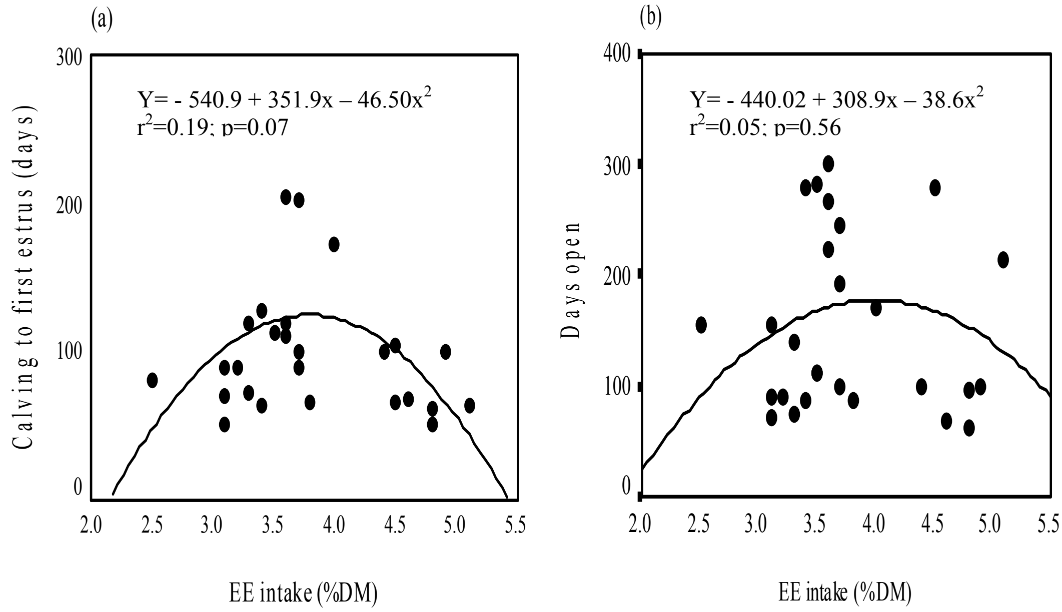


Figure 22 Regressions of (a) days from calving to first estrus (b) days open on dietary EE intake (%DMI) of dairy cows in on-farm farmers' management systems.

A review of the potential mechanism by which fat influences reproduction in dairy cows was reported by Staples *et al.* (1998) to be amelioration of negative energy balance, enhancement of follicular development via changes in insulin status, stimulation of progesterone synthesis and modification of the production and release of prostaglandin F2∝ which influences the persistence of corpus luteum. However, fats rich in linoleic acid suppress prostaglandin F2∝ and prevent regression of corpus luteum (Staples *et al.,* 1998).

Dietary calcium concentration (%DMI) had positive and significant linear correlation with daily actual milk yield (r=0.41; p=0.03) fitting the regression equation, Y=6.11 + 18.02x; but had positive and non-significant linear correlation with FC milk yield (r=0.28; p=0.15) (Figures 23a and b). Inadequate intake of calcium may cause low milk production (McDowell, 1985; Chesworth and Guerin, 1992). Calcium and phosphorus are the two most important mineral elements required both for maintenance and milk production for dairy cows (McDonald *et al.*, 1988). A lactating cow responds to dietary deficiencies of Ca and P by reducing its milk yield without affecting the concentration of the minerals in the milk produced (Underwood, 1981; McDonald et al., 1988). Increased demand for calcium at parturition may also result in milk fever in lactating animals. There was significant quadratic correlation of dietary calcium concentration with milk fat content (r=56; p=0.01), but non-significant and weak linear correlation was observed with milk fat yield (r=17; p=0.40).

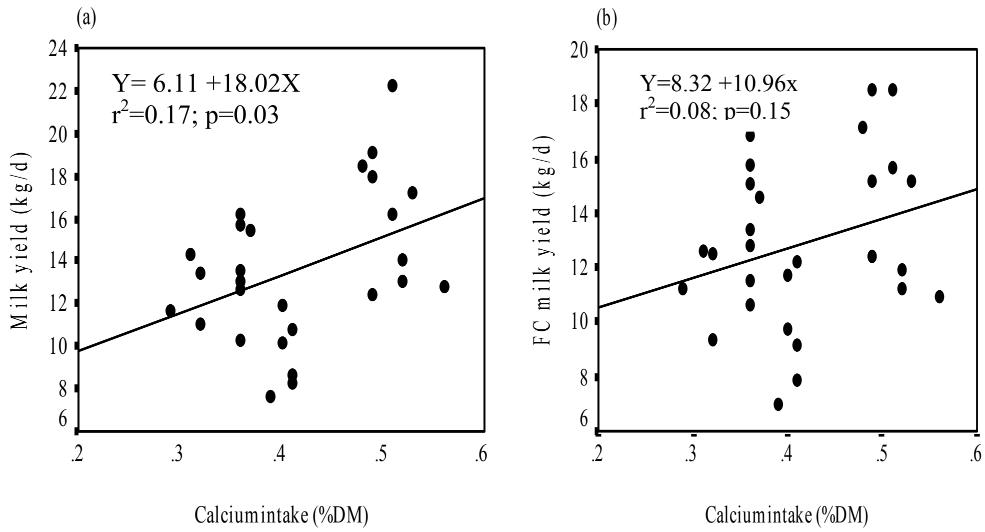


Figure 23 Regressions of (a) daily actual milk yield and (b) FC milk yield on dietary calcium intake (%DMI) of dairy cows in on-farm farmers' management systems.

Dietary calcium concentration had non-significant quadratic correlation with milk protein content (r=0.39; p=0.12), but had linear and non-significant correlation with milk protein yield (r=0.26; p=0.18). The concentrations of milk fat and milk protein in this study tended to decline with increased dietary calcium concentration (Figures 24a and b), which was consistent with the findings of Sanchez *et al*. (1994b), in which there was increased milk fat and protein concentrations with high dietary calcium intake. Calcium intake had also non-significant quadratic correlation with total solid content of milk (r=0.45; p=0.06).

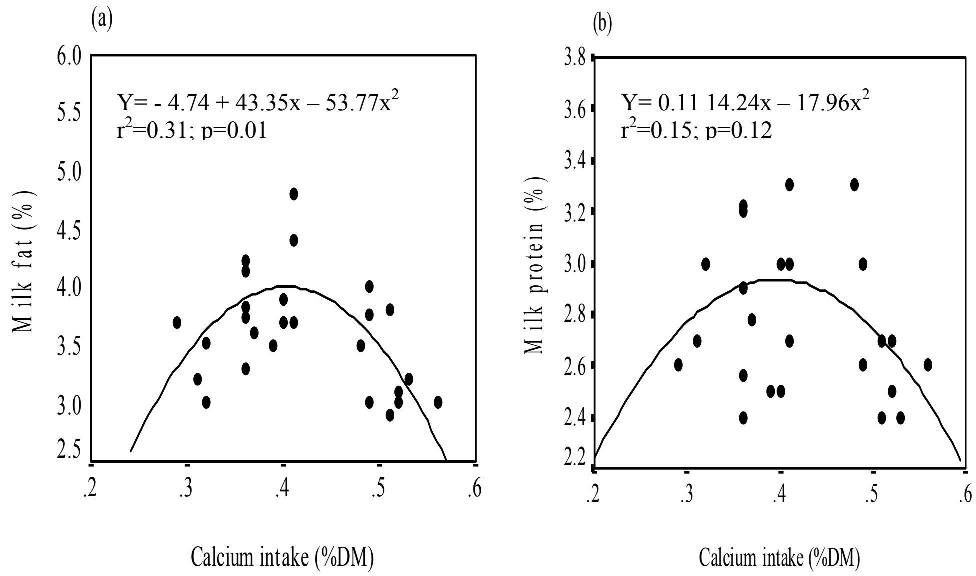


Figure 24 Regressions of (a) milk fat content and (b) milk protein content on dietary calcium intake (%DMI) of dairy cows in on-farm farmers' management systems.

There was non-significant quadratic correlations of dietary calcium intake with days from calving to first estrus (r=0.36; p=0.17) and days open (r=0.29; p=0.32) (Figures 25a and b). The intervals of days from calving to first estrus and days open were tended to increase as the concentration of dietary calcium intake increased above 0.40%. As the level of dietary calcium intake in this study was marginal the lower performances in milk components and reproductive parameters with the increased calcium intake may be attributed to imbalances with other mineral elements. Dietary intake of sodium in this study was lower than the critical level (0.06%) suggested by McDowell (1997). Sanchez *et al.* (1994a) reported that interaction between sodium and calcium significantly influenced dry matter intake, milk yield and FC milk yield responses in dairy cows. Responses to increasing dietary concentrations of sodium were small or negative when concentrations of calcium were low. However, if higher dietary sodium was accompanied by higher calcium, dry matter intake, milk yield and FC milk yield increased.

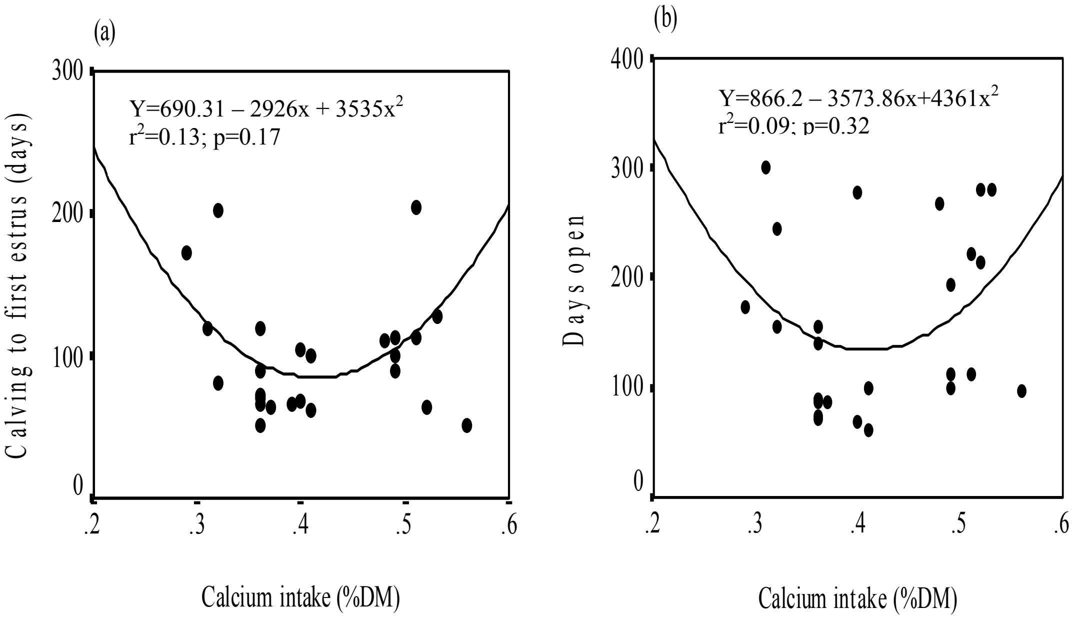
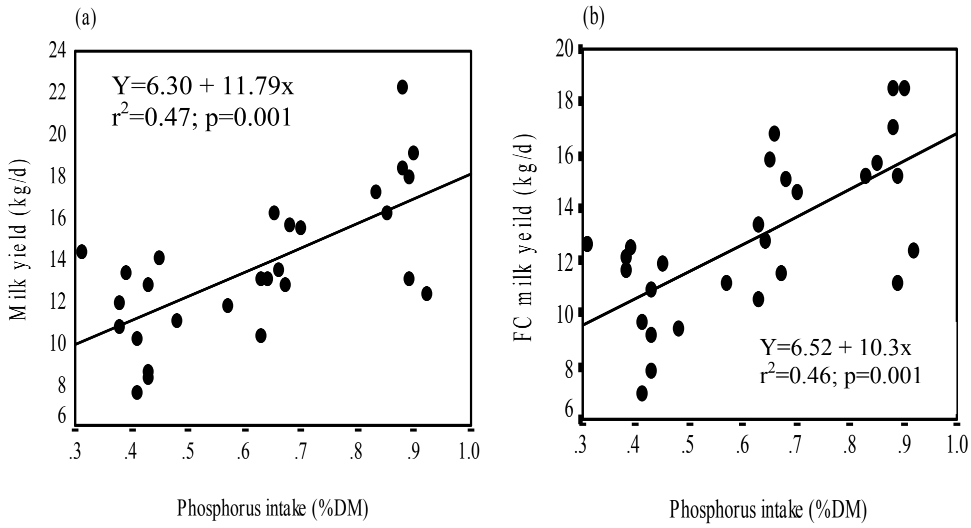


Figure 25 Regressions of (a) days from calving to first estrus and (b) days open on dietary calcium intake (%DMI) of dairy cows in on-farm farmers' management systems.

Dietary intake of phosphorus had positive and significant linear correlations with daily actual milk yield (r=0.68; p=0.001) and 4% FC milk yield (r=0.65; p=0.001) (Figures 26a and b). This result was inconsistent with the findings of Carstairs *et al.* (1981) and Wu *et al.* (2000) in which dry matter intake and milk yield responses of cows in early lactation were maximized with 0.40 to 0.42 percent dietary phosphorus, and greater concentrations (0.50 to 0.52 percent) did not increase dry matter intake and milk yield. However, in this study both actual and FC milk yields were linearly increased as the concentration of dietary phosphorus increased to as high as 0.90 percent. The reason for these differences in response is unclear. It may be related to differences in availability of P with different types of feed resources.



<u>Figure 26</u> Regressions of (a) daily actual milk yield and (b) FC milk yield on dietary phosphorus intake (%DMI) of dairy cows in on-farm farmers' management systems.

There was also positive and significant linear correlation of phosphorus concentration with milk fat yield (r=0.61; p=0.001) and milk protein yield (r=0.61; p=0.001) (Figures 27a and b). But dietary concentration of phosphorus was not correlated with both milk fat and protein contents, and this agrees with the literatures reviewed by NRC (2001). Other reports indicated that, milk protein content increased as phosphorus concentration increased from 0.32 to 0.42 percent compared with 0.24 percent (Call *et al.* 1987). Protein content of milk was higher with 0.45 vs. 0.35 percent phosphorus in a study of Wu and Satter (2000). Milk fat content was also higher with 0.44 vs. 0.35 percent phosphorus (Brodison *et al.* 1989), but lower in a study of Brintrup *et al.* (1993) with 0.33 vs. 0.39 percent phosphorus. Thus there were no consistent effects of dietary phosphorus concentrations on milk compositions among studies.

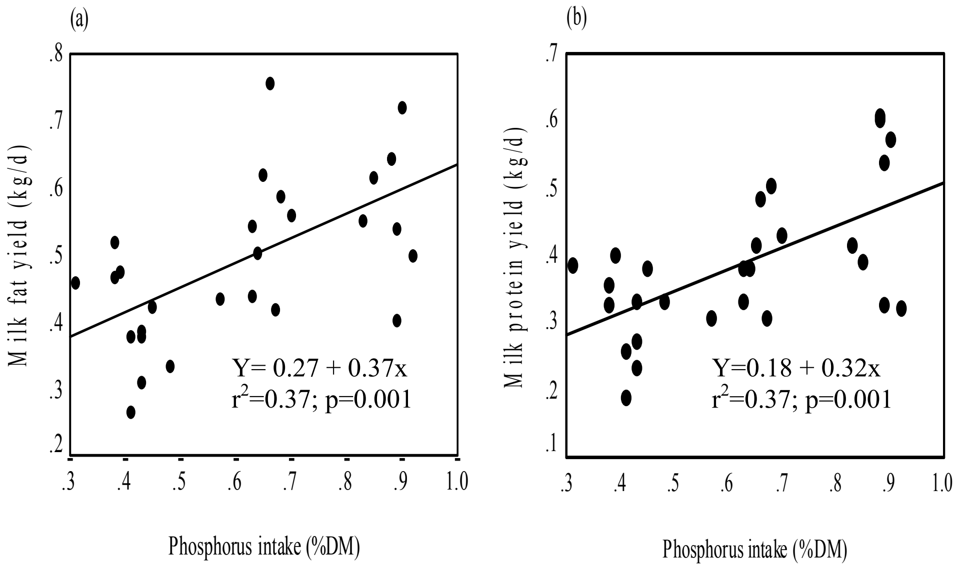


Figure 27 Regressions of (a) daily milk fat yield and (b) daily milk protein yield on dietary phosphorus intake (%DMI) of dairy cows in on-farm farmers' management systems.

There was non-significant quadratic correlation of dietary phosphorus intake with days from calving to first estrus (r=0.41; p=0.09), but significant quadratic correlation was observed with days open (r=0.47; p=0.05) (Figures 28a and b). In this study dietary phosphorus concentrations of either lower than 0.50% or above 0.80% (dry matter basis) tended to increase both days from calving to first estrus and days open. Between 0.50 and 0.80 percent of phosphorus concentration the values of days from calving to first estrus and days open were closer to the regression line and variations among individual observations were relatively low. Wu and Satter, (2000) reported that, as long as dietary phosphorus concentration was greater or equal to 0.32 percent, reproductive performance was normal and not improved with greater concentrations of phosphorus. By feeding 0.35 or 0.45 percent dietary phosphorus days to first insemination, days open and services per conception were not affected. But in this study days open was affected by dietary phosphorus concentration. This result was similar with the trends observed in the relationship of dietary calcium with reproductive parameters in this study, indicating that high intake of dietary phosphorus along with low calcium intake depresses reproductive performances in dairy cows (Shaver and Howard, 2005).

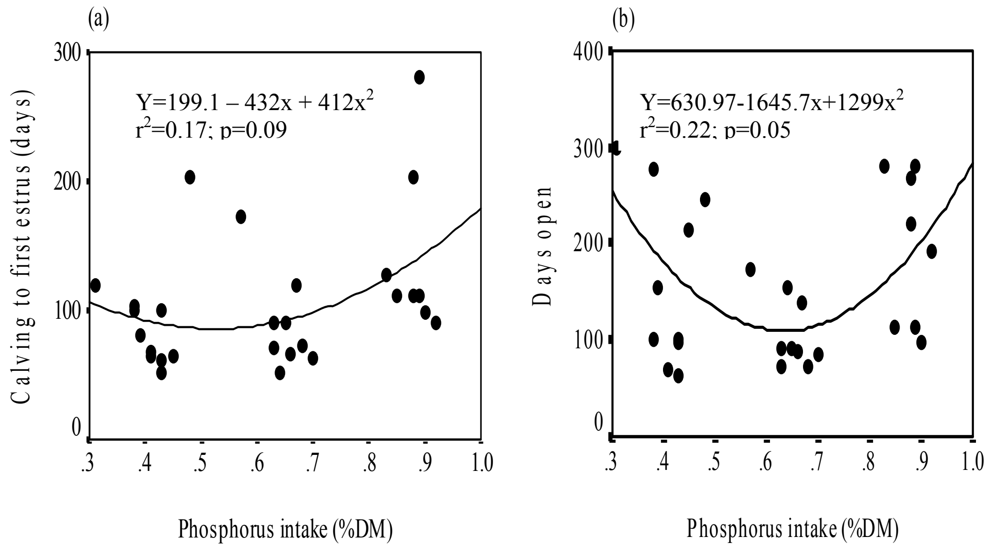


Figure 28 Regressions of (a) days from calving to first estrus and (b) days open on dietary phosphorus intake (%DMI) of dairy cows in on-farm farmers' management systems.

Dietary sodium concentration (%DMI) in this study was below the critical level reported by McDowell (1997). Even though, sodium is considered to have significant influence on productivity of dairy cattle it had weak and non-significant positive correlations with actual milk yield (r=0.19; p=0.33), FC milk yield (r=0.23; p=0.23), milk fat yield (r=0.23; p=0.23) and milk protein yield (r=0.12; p=0.54). Mallonee *et al*. (1982a) reported that feeding lactating dairy cows a diet with no supplemental sodium chloride resulted in marked depression in dry matter intake and milk yield after 1 to 2 weeks of lactation. Effects of dietary sodium supplementation on dry matter intake and milk yield response of dairy cattle can be also influenced by the concentrations of other macro mineral elements in the diets (Sanchez *et al.,* 1994a, and b). There were interactions of sodium by potassium, sodium by chloride and sodium by phosphorus on dry matter intake indicating that responses to sodium differed, over the range of dietary concentrations of these mineral elements (Sanchez *et al.,* 1994a, and b).

Cost-benefit relationship of milk production

Comparative cost-benefit relationship of 305 days milk production on small and large scale farms is presented in Table 10. About 21% higher gross margin was recorded on large scale farms than on small scale farms. This may be partly due to higher input on the large scale farms in terms of regular feed supply as compared to those of small scale farms. This is consistent with the diverse milk production systems in the other tropical regions (Leng, 1991). In some cases, milk production is extremely high due to high technological inputs, while in other cases lactation milk yield is far below the animals' genetic potential due to limited inputs. The efficiency of milk production is a function of income from farm output (B) mainly from milk sale and costs of milk production (A). Therefore, in order to increase the efficiency of a farm, one need to increase output and reduce costs of inputs (Chantalakhana, 1999).In addition to the lower quantities of feed supply in small scale farms, the quality of available feed resources may not support expected level of milk production as compared to that in large scale farms.

Table 10 Comparative gross margin of milk production on small and large scale farms for 305 lactation days.

Descriptions	Small scales		Large scales	
	Values (Eth. Birr))	% Total	Values[C] (Eth. Birr))	% Total
A. Inputs				
1. Feed costs				
1.1. Roughage	616.10	23	835.70	16.6
1.2. Supplement	1,250.50	47	3,309.25	65.70
2. Labor costs	762.50	29	854.00	16.9
3. Medication and AI	27.25	1	40.15	0.80
Total input	**2,656.35**	**100**	**5,039.10**	**100**
B. Outputs				
1. Value of milk	5,261.25		8,192.30	
Total output	**5,261.25**		**8,192.30**	
Gross margin	**2,604.90**		**3,153.20**	

[C]1 USD = 8.68 Ethiopian Birr.

On the other hand, the smallholder farmers participated in this study had critical problems of reliable access to market out-let for their fresh milk produced and consequently the average selling value of fresh milk on small scale farms was Ethiopian Birr 1.50 per kg as compared to that of Ethiopian Birr 1.70 per kg on large scale farms.

Feed cost was the major cost center in both farming systems accounting for about 70 and 82% in small scale and large scale farms respectively. Besides improved genetic potential of the animals, cost effective feeding practice, level of farmers' management skills, proper health care and reproductive efficiencies are the major prerequisite for profitability of any dairy enterprise.

EXPERIMENT 2 Productive and reproductive responses of lactating cows fed on grass hay and concentrate supplement with/without cottonseed cake and/or bole.

Chemical compositions of experimental feeds

Chemical compositions of the grass hay and the experimental diets are presented in Table 11. Grass hay was deficient in contents of CP and EE; lower in *in-vitro* organic matter organic matter digestibility (IVOMD) and high in NDF content as expected. Its Ca content was slightly higher than the critical level and also inconsistent with the report of Vijchulata (1998) for different species of grasses in northern Thailand. The slightly higher Ca content (0.40 % DM) of hay in this study may due to the differences in the type and fertility of the soil or differences in the species and composition of the grass. The compositions of the grass in this study were *Digitaria, Eragrostis and Trifolium* species unlike the pure stand grass varieties reported by Vijchulata (1998). The concentrations of P, Na and Mg were also deficient and below the critical levels of 0.25, 0.06, and 0.20 % (dry matter basis) respectively suggested by McDowell (1997), while K and Mn contents were sufficiently high for ruminant. The concentrations of mineral elements in forage depend upon several factors such as soil, plant species, stage of maturity and climate (Chesworth and Guérin, 1992; McDowell, 1997). The dietary concentrate mixtures of all treatment groups were sufficiently high in CP, NDF, EE and ash contents and IVOMD. Substitution of concentrate diet with 45% cottonseed cake in the two dietary treatments (C+ CSC and C+CSC+ Bole) increased NDF and EE contents by about 23 % relative to the control treatment group. Calcium, P, Na, K, Mg and Mn contents of all the concentrate mixtures were sufficiently higher than the requirement levels of 0.25 to 0.48, 0.06 to 0.25, 0.80 to 1.20, 0.19 to 0.30 (dry matter basis) and 40 to 100 mg/kg DM respectively (McDowell, 1997).

Table 11 Mean chemical compositions of the experimental diets for cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Experimental diets	(%DM)												(mg/kg)	Ca: P[c] ratio
	DM%	CP	OM	NDF	EE	Ash	IVOMD	Ca	P	Na	K	Mg	Mn	
Hay	91	4.9	92	72	1.17	8.35	46.3	0.40	0.17	0.02	1.48	0.17	340	2.4:1
C (control)	89	20.1	89	39	5.07	10.96	66.9	1.17	0.88	0.48	1.09	0.41	147	1.3:1
C + CSC[a]	90	21.9	92	46	6.18	8.47	62.5	0.74	0.82	0.39	1.22	0.38	82	0.9:1
C + bole[b]	90	20.2	84	32	4.31	15.94	66.5	1.12	0.83	1.39	1.03	0.39	151	1.4:1
C + CSC + bole	91	21.9	88	47	5.70	11.83	63.0	0.79	0.77	0.88	1.16	0.38	98	1:1
CSC alone	95	24.9	94	48	7.8	5.6	55.7	0.21	0.86	0.02	1.33	0.35	8.8	0.24:1
Bole (soil)	-	-		-	-	-	-	0.21	0.04	36.84	1.13	0.08	11	5.3:1
Critical levels of minerals [c]	-	-	-	-	-	-	-	0.30	0.25	0.06	0.60-0.80	0.20	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).

The Ca concentration in the control concentrate (C) and concentrate plus bole (C+ bole) diets were higher than that in concentrate plus cottonseed cake (C + CSC) and concentrate plus cottonseed cake with bole (C+ CSC + bole) diets. 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. The ratio of Ca to P in the dietary treatments of concentrate alone and concentrate plus bole soil were sufficiently high, but in the other two treatments where CSC was included it was below critical levels suggested by McDowell (1997).

Sodium contents of C+ Bole and C+ CSC + bole were higher than the treatment diets of C and C+ CSC due to the inclusion of bole which had higher concentration of Na. All treatment diets were almost similar in the contents of P, K and Mg. Crude protein content of cottonseed cake (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 (NRC, 1989; Smith *et. al.,* 1981). The low crude protein content of cottonseed cake in this study may be attributed to either mechanical method used for oil extraction or due to high hull content of the seed as a result of .poor processing during de-hulling. Shem *et al*. (2003) and Sarwatt *et al*. (2004) observed similar results that cottonseed hulls have negative effect on crude protein content of the feed.

Dry matter disappearance and rumen degradability characteristics

Rumen dry matter disappearances of the experimental feeds at different hours of incubations were presented in Table 12 and Figure 29. Throughout the incubation hours, rumen dry matter disappearances were significantly ($p<0.001$) different among treatments. Dry matter disappearance of the two dietary supplements with 45% cottonseed cake were significantly ($p<0.001$) lower than those of the concentrate (control) and concentrate plus 3% bole throughout the incubation hours. This can probably be due to relatively higher NDF and cell wall content of cottonseed cake in these diets. Shem *et al.* (2003) reported that higher cell wall content reduced dry matter degradability of cottonseed cake.

Table 12 Rumen dry matter disappearance of the experimental diets (%DM).

Incubation time (hrs)	Treatments				SE	p
	Conc. alone	Conc.+ CSC	Conc.+ bole	Conc.+ CSC+ bole		
0 (wash value)	42.21[a]	32.44[c]	43.34[a]	34.94[b]	0.37	***
3	60.35[a]	47.96[b]	61.26[a]	50.26[b]	0.34	***
6	66.35[a]	50.13[b]	65.58[a]	53.15[b]	0.44	***
12	68.83[a]	55.94[b]	69.06[a]	53.42[b]	0.31	***
24	75.57[a]	61.86[b]	74.21[a]	63.79[b]	0.49	***
48	82.47[a]	74.45[b]	80.70[a]	69.13[c]	0.65	***

*** = p<0.001.
Conc. = concentrate; CSC = Cottonseed cake.
[a, b,] means with the different superscripts in the same row are significantly different (p<0.05).

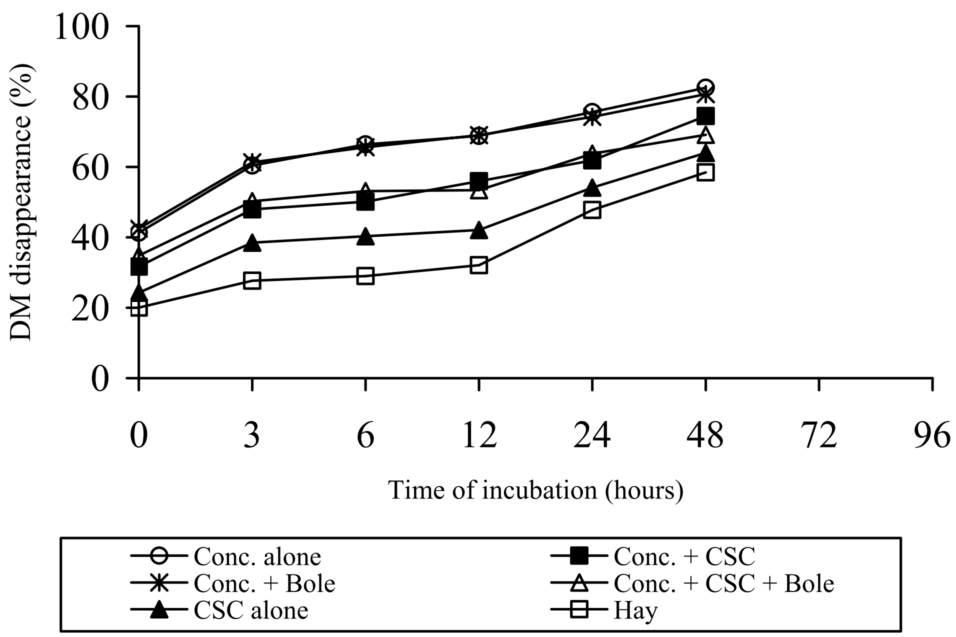


Figure 29 Rumen degradability percentages of feeds dry matter used in the experiment over time.

Dry matter degradation constants of the experimental diets were presented in Table 13. Dietary treatments with 45% cottonseed cake were significantly (p<0.001) lower in readily soluble fractions (a) than the concentrate alone (control) and concentrate plus 3% bole. The results of the readily soluble fractions (a) followed similar trends observed with dry matter disappearances of these diets. The insoluble but slowly rumen degradable fraction (b) was not significantly (p>0.05) differed among treatments. However, higher values of slowly rumen degradable fractions (b) were recorded for the two diets with 45% cottonseed cake than the concentrate alone and concentrate plus 3% bole diets. The rate of degradation of b per hour (c/hour) was significantly (p<0.05) different among treatments. Highest rate of degradation (0.065) was observed for the control diet, while that of the control + CSC + bole was the least. (0.028). Depression in the rates of degradation of diets with 45% CSC relative to the other dietary treatments could have been also caused by high NDF content of cottonseed cake. But the depression in the rate of degradation with the inclusion of 3% bole was unclear. There was no significant (p>0.05) treatment effects on the potentially degradable fractions (a + b) of the diets. However, the values for two treatment diets with 45% cottonseed cake were relatively lower than those of the control and the control + bole. Generally, the lower values of readily soluble fraction, higher values of slowly degradable fractions, lower rates of degradation and lower potentially degradable fractions of the two diets with 45% CSC reveals the longer retention time and relatively higher rumen bypass property of cottonseed cake.

Table 13 Dry matter degradation constants of concentrate diets supplemented with/without cottonseed cake and/or bole.

Degradation constants (%DM)	Concentrate alone	Concentrate + CSC	Concentrate + bole	Concentrate .+CSC+ bole	SE	p
a	59.35^{a}	46.31^{b}	60.06^{a}	48.45^{b}	0.24	***
b	24.70	32.60	24.08	30.10	0.19	NS
c/hr	0.065^{a}	0.048^{ab}	0.043^{b}	0.028^{bc}	0.001	*
PD (a+b)	84.05	78.91	84.14	78.55	0.20	NS
TL (hr)	1	1	1	1		

$^{a, b}$ means with different superscripts in the same row are significantly different (p<0.05).
* = p<0.05; *** = p<0.001; a=intercept; b=potentially, but slowly degradable component; c=rate of degradation of b; PD=potential degradability (a + b).

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 14. Daily intakes of hay was significant ($p<0.05$) between treatments. There was 3.42, 10.43 and 13% higher intake of hay for animals supplemented concentrate diet with cottonseed cake (C + CSC), bole (C + bole) and combination of cottonseed cake and bole (C + CSC + bole) respectively. The intake of grass hay was depressed in animals fed a concentrate diet with CSC alone and this is consistent with the report of Wanapat *et al.* (1996) in which the intake of rice straw was depressed with increased level of cottonseed meal above 4 kg/d/head in dairy cattle. 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 by animals fed a concentrate diet with CSC and/or bole soil than the control group. Daily CP intake of animals in 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 in treatment C + Bole and C+ CSC + bole were nearly at requirement level. Daily intake of ME 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 14).

Table 14 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/d)	1,944	2,179	2,103	2,300	188.51	NS
CP Requirement (g/d)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/d)	132	131	142	140	6.16	NS
ME Requirement (MJ/d)y	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	**
Hay NDF (% total NDF)	57.2[b]	53.6[b]	62.3[a]	54.8[b]	1.69	***
EE (%DMI)	3.4[c]	4.05[a]	2.90[d]	3.8[b]	0.08	***
Nonstructural carbohydrate (%DMI)	20.3[a]	15.9[b]	22.3[a]	14.5[b]	0.93	***

[d] C= concentrate; CSC = Cottonseed cake.
[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).

Significant differences were also observed in the dietary intakes (%DMI) of NDF (p<0.01), EE (p<0.001) and NSC (p<0.001) among treatments (Table 14). Relatively higher intakes of NDF and EE (%DMI) were observed by animals fed a concentrate diets substituted with 45% 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 Nocek and Russell (1988). 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 (Shaver, 2006).

Dietary intakes of certain minerals considered in this study are presented in Table 15. Significant differences were observed in the dietary intakes (%DMI) of calcium (p<0.001), phosphorus (p<0.01), sodium (p<0.001), potassium (p<0.001), magnesium (p<0.01) and manganese (p<0.001) among treatments. Dietary intake of

Ca in the treatment diets with 45 % cottonseed cake was marginal (0.60 % DMI) due to the lower concentration of the element in cottonseed cake. However, its intake in the control diet (C) and control plus bole was sufficiently high (1.08 and 1.14 % DM respectively) than the recommended requirement of 0.48 to 0.77 % (McDowell, 1997; NRC, 2001).

Table 15 Estimated dietary intakes of certain minerals by lactating cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Mineral elements	Conc. alone	Conc.+ CSC	Conc. + bole	Conc.+ CSC+ bole	SE	p	Requirements[@]
Calcium (%DMI)	1.08[b]	0.59c	1.14[a]	0.62[c]	0.02	***	0.48 – 0.77
Phosphorus (%DMI)	0.58[a]	0.54[a]	0.55[a]	0.51[b]	0.01	**	0.25 – 0.48
Sodium (%DMI)	0.29[c]	0.16[d]	0.81[a]	0.51[b]	0.01	***	0.06 – 0.25
Potassium (%DMI)	1.26[c]	1.33[a]	1.22[d]	1.30[b]	0.01	**	0.80 – 1.20
Magnesium (%DMI)	0.31[a]	0.29[b]	0.30[b]	0.29[b]	0.004	**	0.19 – 0.30
Manganese (mg/kg DM)	228.60[a]	191.80[c]	231.35[a]	201.45[b]	3.75	***	40 - 100
Ca : P ratio	1.9:1[b]	1.09:1[d]	2.08:1[a]	1.2:1[c]	0.01	***	1:1 to 2:1

[@] Adapted from McDowell (1997).
**=p<0.01; ***=p<0.001.
[a, b,] means with the different superscripts in the same row are significantly different (p<0.05).

Throughout the treatment groups, the intake of dietary phosphorus was sufficiently higher (0.51 – 0.58 % %DMI) than the suggested level of requirement (0.25 – 0.48 % DM) by McDowell (1997). Although the intake of Na for all treatment diets was sufficiently higher (0.16 – 0.81 % DM) than the requirement (0.06 – 0.25 % DM), the levels in the dietary treatments with 45 % cottonseed cake were depressed due to lower concentration of Na in cottonseed cake (Table 11). Dietary intakes of K, Mg and Mn were also sufficiently higher than the suggested ranges (McDowell, 1997; NRC, 2001) of 0.80 to 1.20, 0.19 to 0.30 (dry matter basis) and 40 to 100 mg/kg DM respectively. The ratios of calcium to phosphorus throughout the dietary treatments were marginal and with in the range recommended (1:1 to 2.1) by McDowell (1997).

Milk yield, milk composition and milk production efficiency

Daily actual milk yield, FC milk yield, milk composition and milk production efficiency of cows fed hay and a concentrate supplement with/without cottonseed cake and/or bole is presented in Table 16. Daily actual milk yield and FC milk yield were not significantly ($p>0.05$) different among treatments. However, higher daily actual milk yield and FC milk yield were recorded by animals supplemented a concentrate diet with either CSC alone, 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. The lower milk productivity of animals fed the concentrate diet with 45% CSC alone than those fed a concentrate diet with bole alone or the combination of bole and CSC can be related to the relatively lower intake of hay and dietary supplement and consequently lower total dry matter intake. Generally, milk yield was linearly increased with increased dry matter intake. 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 (Preston and Leng, 1987). Actual and FC milk yields tended to increase with the decreased rate of rumen dry matter degradability of the diets (Table 13).

Table 16 Means of milk yield, milk composition, reproductive efficiency and efficiency of feed utilization by lactating cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Parameters	Treatments [d]				SE	p
	C	C+CSC	C+ bole	C+CSC+ bole		
Milk yield (kg/d)	15.19	16.32	17.66	17.95	1.26	NS
FC milk yield (kg/d)	13.97	15.97	17.35	17.56	1.31	NS
Fat (%)	3.43^b	3.81^a	3.86^a	3.81^a	0.11	*
Fat yield (kg/d)	0.53^b	0.63^a	0.69^a	0.69^a	0.06	*
Protein (%)	2.48	2.50	2.54	2.45	0.07	NS
Protein yield (g/d)	0.38	0.41	0.45	0.44	0.04	NS
Protein yield (%CP intake)	18.96	18.87	21.32	19.00	1.26	NS
Total solid (%)	11.00	11.20	11.44	11.44	0.28	NS
Kg milk/kg supplement	1.91^b	1.88^b	2.11^a	2.05^a	0.10	*
Kg milk/kg DM intake	1.10	1.09	1.21	1.18	0.06	NS
Supplement cost/kg milk (Birr)[c]	0.58^a	0.56^a	0.49^b	0.55^a	0.02	*
Calving to first estrus (d)	79.60	88.60	71.30	73.00	16.30	NS
Days open	101.90	148.20	86.40	114.00	22.36	NS
Service per conception	1.60	2.00	1.40	1.90	0.42	NS

* = p<0.05; FC = fat corrected; C= concentrate; CSC = Cottonseed cake.
[c]1USD=8.68 Ethiopian Birr.
[a, b], means with different superscripts in same row are significantly different (p<0.05).

This may be due to proportional supply of some rumen bypass protein to the lower digestive tracts. Although statistically not significant (p>0.05), the 7.4% and 14.3% increase of actual and FC milk yield respectively in animals fed a concentrate diet with CSC alone than those fed the control diet was partly consistent with the report of Smith *et al.* (1981) which revealed that substitution of total mixed ration with different levels of whole cottonseed did not significantly affect DM intake or milk yield of Holstein Friesian cows, but increased milk fat and FC milk yield. Wanapat *et al.* (1996) also reported that supplementing low protein basal diet of rice straw and cassava chips with different levels of cottonseed meal (2, 3, 4 and 5 kg/d/head) in crossbred Holstein-Zebu cows linearly decreased straw intake, but increased the production of milk up to 4 kg/d/head of cottonseed meal. But milk yield was depressed with 5 kg/d/head.

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 supplemented with CSC alone. This may be attributed to sufficiently higher intakes of Na (0.81 and 0.51 %DM respectively) in the diets than needed for requirements (Table 15). Sanchez *et al*. (1994a, b) and Berger (1994) reported that dry matter intake and milk yield was improved by dietary concentration of Na above those needed to meet requirements. Dry matter intake and milk yield responses over a range of dietary Na concentrations (0.11 to 1.2 %DM) were curvilinear, with maximum performance at 0.70 to 0.80 percent of dry matter (Sanchez *et al*., 1994a, b). Sanchez *et al*. (1994a, b) further reported that there was higher DM intake and milk yield responses at higher concentration of K above those needed to meet requirements. Dry matter intake and milk yield responses over a range of dietary potassium concentrations (0.66 to 1.96 %DM) were curvilinear, with the maximum performance when diets contained 1.50 percent potassium, dry matter basis. Maximum feed intake and milk yield responses at higher concentrations of potassium than needed to meet requirements likely are associated with the higher concentrations of sodium. Interactions of potassium by sodium on DM intake and milk yield indicated that responses to potassium differed over the range of dietary concentrations of sodium.

In addition, as soils are usually considered to influence indirectly animal nutrition through the quantity and quality of herbage they produce, there is also direct soil-animal effect (McDowell, 1985). Ingested soil provides a source of essential elements, and improves the utilization of energy and increases the availability of certain minerals (Miller *et al.,* 1978). 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 Miller *et al.* (1978) 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.

Lactation curve over 18 weeks of lactation for animals fed hay and concentrate supplement with/without CSC and/or bole is presented in Figure 30. Animals fed a concentrate diet alone (control) had slower increase of milk yield up to the peak of 17.5 kg at week 7, while those fed on a concentrate diet with CSC alone had relatively faster and sharp increase, but attained peak yield of 18.3 kg shortly at week 5.

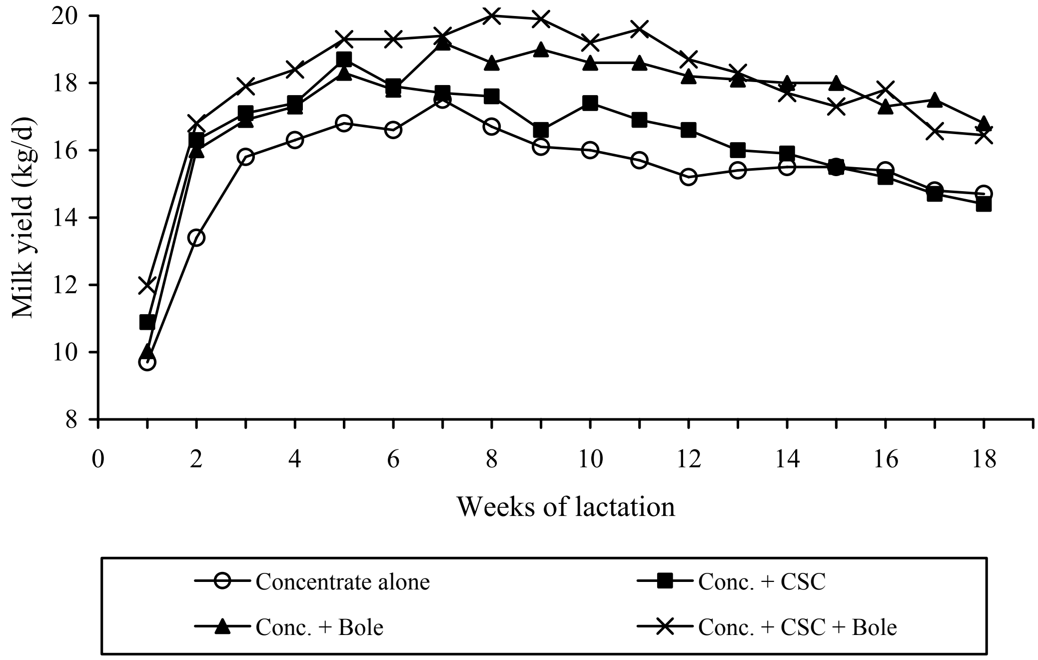


Figure 30 Mean weekly milk yield of cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

The treatment group fed on a concentrate diet with bole had faster and sharp increase until week 5, from where the trend of increase became slow until the peak yield of 19.2 kg at week 7 and the trend of decline after peak yield was relatively slow and flatter than the other groups. Similarly the group supplemented with the combination of CSC and bole had faster increase until week 5 and then after became slow until the peak yield of 20 kg at week 7. Despite the shorter and lower peak yield the trend of decline after peak yield at week 7 for this group was almost flatter as compared to other groups.

There was significant ($p<0.05$) treatment effects on milk fat content and yield. Inclusion of CSC alone, bole soil alone or the combination CSC and bole soil increased fat content by about 10%, 11% and 9% respectively and daily fat yield by 3%, 27% and 21% respectively than the control diet. Inclusion of CSC and/or bole equally increased milk fat content. The reason for the increase in milk fat content and yield by animals fed concentrate diet with 3% bole was unclear. However, it can be suggested that bole soil may have a buffering effect on the rumen environment of the animals under these treatment diets and this may resulted in decreased ruminal propionic acid production and increase the ratio of acetic acid to propionic acid favoring of milk fat yield (Rogers *et al.,* 1982). However, the buffering effect of bole on the rumen environment needs further assessment. Rogers and Davis (1982a) reported that the improvement in animal performances when high concentrate diets were supplemented with sodium bicarbonate as a buffer was attributed to increased pH which enhanced ruminal fermentation and increased rumen fluid outflow. In Ethiopia milk processing plants consider level of milk fat content as one of the main quality criteria to accept fresh milk from dairy farmers. They accept fresh milk with at least 3.5% fat content and that with 4% fat is more preferred. Therefore, milk producers may attract more market for their fresh milk if they can include bole in the concentrate diet of their lactating cows.

There was no significant ($p>0.05$) treatment effects on milk protein content and yield. Generally, milk protein content throughout the treatments groups in this study was lower than expected. The efficiency of milk protein production (expressed as a percentage of dietary CP intakes) was not significant between treatments and also lower than the values reported by other workers (Arieli *et al.,* 2004). This may be due to lower ME supply of the diets than the estimated levels of requirement (Table 14). Energy intake either through concentrate or roughage ingredients have significant influence on the percentage and yield of milk protein (DePeters and Cant, 1992). Coulon and Rémond (1991) reported that milk protein content increased linearly with energy supply, except from fat addition (Emery, 1978; Grieve *et al.,* 1986; Macleod *et al.,* 1983). In this study the dietary ME intake was lower than the estimated requirement, while CP intake was higher than requirement. Therefore, the results of milk protein content and yield in this study is inline with the reports of Gordon and Forbes (1970) in which milk protein tended to increase with increasing energy intake with a low protein diet but not with a high protein diet. The declining tendency of milk protein efficiency with the surplus CP supply in our study (Table 16) also agrees with the findings of Arieli *et al.* (2004) in which milk protein production efficiency tended to increase from 0.29 in the high protein (HP) diet to 0.31 in the low protein

(LP) diet. How ever, in their study the energy supply was adequate to support higher milk protein yield. Milk protein content and yield can also be increased by improving the profile of amino acid in microbial protein, by reducing the amount of surplus protein in the diet, and by increasing the amount of fermentable carbohydrate in the diet (Macleod *et al.*, 1983; Stobbs and Brett, 1974; Clark, 1975).

In addition, the lower dietary concentration of non structural carbohydrate than optimum range of 30 to 46 % (dry matter basis) throughout the treatments (Table 14) may contribute to the lower milk protein contents and yield. Non structural carbohydrate rapidly and completely ferments in the rumen and increases the energy densities of the diets, which improves the energy supply and determine the amount of bacterial protein (BCP) produced in the rumen. Milk protein concentration can be lower with reduced BCP supply caused by lack of ruminally fermented energy (NRC, 2001). In another study, the percentage and yield of milk protein was increased when NSC in the dietary DM was increased from 41.7 to 46.5 percent (Minor *et al.,* 1998). Ruminally synthesized BCP is the major source of essential amino acids to be supplied to the lower digestive tract. Since milk protein content also depends on the supply of essential amino acids, lysine and methionine in particular (Rulquin *et al.,* 1993), limitations in the supply of BCP consequently limit milk protein content of dairy cows (NRC, 1989). Inadequate energy intake and feeding of highly degradable protein in early lactation produced excess ammonia in the rumen, high blood and milk urea concentration, but the concentration of milk protein was low (Emery, 1978). Total solid content of milk was not significantly ($p>0.05$) affected by treatments in this study.

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. Daily milk yield per kg supplement was significantly ($p<0.05$) different among treatments. Animals fed a concentrate supplement with bole alone or with the combination of bole and cottonseed cake produced similar and higher milk than the other groups. There was significant ($p<0.05$) treatment effect in costs of supplement per kg of daily milk yield

(Table 16). A lower cost of supplement for animals fed on concentrate diet supplemented with bole alone followed by 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.

Reproductive Efficiency

Effects of supplementing a concentrate diet with cottonseed cake and/or bole on reproductive efficiency of lactating cows is presented in Table 16. Statistically no significant ($p>0.05$) effects of treatments were observed on all the reproductive parameters. However, there were shorter days from calving to first estrus (71d), 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 control plus cottonseed cake (88.6 days, 148.2 days and 2.0), and the control plus cottonseed cake plus bole (73 days, 114 days and 1.9) respectively. The relatively poor reproductive efficiencies of 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. Jordan and Swanson (1979a) reported that cows fed excess total protein produced more milk and showed signs of standing oestrus earlier after calving as compared to groups of cows received lower CP. However, they tended to have lower conception rate and consequently were open longer and required more services per conception. The low reproductive efficiencies of animals fed the two dietary treatments of Concentrate + CSC and Concentrate + CSC + bole can be 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. The functioning of normal estrous cycle activity after calving also depends on the energy balance of the animals (Lanyasunya *et al*., 2005).

The relatively higher intake of dietary calcium (1.14 %DM), sodium (0.81 %DM) and manganese (231.35 mg/kg DM) as well as the optimum ratio of calcium to phosphorus (2.08: 1) in the diet (Table 15) 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 relatively lower concentrations of these elements in the control diet (1.08, 0.29, 228.6 and 1.9: 1), control plus cottonseed cake (0.59, 0.16, 191.8 and 1.09: 1) and control plus cottonseed cake plus bole (0.62, 0.51, 201.5 and 1.2: 1) respectively. The longer days from calving to first observed estrus, days open and higher number of services per conception for animals fed a concentrate diet with cottonseed cake alone may be due partly to marginal concentrations of calcium, sodium and magnesium in this dietary treatment. Mineral supply is strongly associated with reproductive performances of dairy cows (Lanyasunya *et al*., 2005). 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 (Shaver and Howard, 2006). 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, Concentrate + CSC and concentrate + CSC + bole, as those fed the concentrate (control) or concentrate + bole treatments, may be due to marginal levels in the concentration of calcium in these treatment and the interaction of the two mineral elements. Shaver and Howard (2005) 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. Lanyasunya *et al.* (2005) 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 CSC was depressed and can be associated 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 (Rojas *et al*., 1965).

Although it improved actual milk yield, FC milk yield, and milk fat content, supplementing a concentrate diet with CSC alone or in combination with bole increased the days from calving to first observed estrus, days open and number of services per conception, but had no significant effect on milk protein content and yield. Inclusion of 3% bole alone improved the yields actual and 4% fat corrected milk, milk fat content and yield and the reproductive parameters measured. It was also economically profitable.

CONCLUSION AND RECOMENDATIONS

Highest milk yield was recorded on large scale farms than on small scale farms which can be related to relatively consistent feed supply and consequently higher dry matter intake. But milk components and reproductive efficiencies were not significantly differed between farm scales. Milk yield, milk components and reproductive parameters measured were not affected by parity classes. Generally the productivity of animals on both farm scales was below their expected genetic potential; particularly that of small scale farms was critically low as compared to some parts of the tropics. The amounts of CP (g/d/head) and ME (MJ/d/head) consumed were above the requirement for the observed actual milk out put. However, the proportion of rumen degradable to undegradable CP and that of structural and none structural carbohydrate needs further investigation. Regardless of its biological availability, calcium intake was also at marginal level. The supplies of minerals particularly on small scale farms were unbalanced. There was also lower ratio of Ca: P in both farm scales. Sodium intake (%DMI) was also critically lower than the recommended level of 0.18% (NRC 1989). The large variation among individual animals and within the farm scales shows variations in feeding managements and there are opportunities for further improvement. There will be a need to investigate the nutrient balance of available feed supply for both farm scales. The ratio of rumen degradable to that of un-degradable protein must be assessed and adjusted to the recommended level. The nutritional values of the home-made liquor residues used by most small scale farmers have to be assessed further. The need of technical and institutional support will be indispensable to ensure sustainable supply of nutritionally balance feeds; AI and veterinary services which are the major areas of research and development intervention. This may need establishment of dairy farmers cooperatives in the study area, in which other farmers else where were successful in getting access to regular animal feed supply and market out-let for their products.

Supplementing a concentrate diet with 45% cottonseed cake improved both actual and fat corrected milk yield, but it was biologically and economically less attractive than utilizing bole alone. Supplementing a concentrate diet with 3% bole alone was found biologically and economically profitable. It is well known that milk processing plants in and around Addis Ababa consider the level of milk fat content as one of the major quality criterion to accept fresh milk from producers. The improved milk fat content with the inclusion of 3% bole in a concentrate diet can attract market for fresh milk produced by the dairy farmers. However, optimum levels of cottonseed cake and bole to be included in a concentrate diet have to be assessed further.

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APPENDIX

Appendix Table 1 Analysis of variance for effects of farm scales and parity classes on milk yield of dairy cows in the urban and peri-urban centers of central rift valley, Oromia.

Sources	df	SS	MS	F	p=
Model	2	131.2322	65.6161	8.82	0.001
Farm scale	1	128.8716	128.8716	17.33	0.001
Parity classes	1	2.3606036	2.3606036	0.32	0.58
Error	25	185.938804	7.4		
Total	28	317.1710107			
Coefficient of variation = 20.04					

Appendix Table 2 Analysis of variance for effects of farm scales and parity classes on 4% FC milk yield of dairy cows in the urban and peri-urban centers of central rift valley, Oromia.

Sources	df	SS	MS	F	p=
Model	2	90.8585714	45.4292857	7.28	0.003
Farm scale	1	88.57285714	88.57285714	14.19	0.001
Parity classes	1	2.28571429	2.28571429	0.37	0.55
Error	25	155.9685714	6.2387429		
Total	28	246.8271429			
Coefficient of variation = 19.39					

<u>Appendix Table 3</u> Analysis of variance for effects of farm scales and parity classes on milk fat content of dairy cows in the urban and peri-urban centers of central rift valley, Oromia.

Sources	**df**	**SS**	**MS**	**F**	**p=**
Model	2	0.38332143	0.19166071	0.52	0.60
Farm scale	1	0.34543214	0.34543214	0.93	0.34
Parity classes	1	0.03788929	0.03788929	0.10	0.75
Error	25	9.29588929	0.37183557		
Total	28	9.67921071			
Coefficient of variation = 16.58					

<u>Appendix Table 4</u> Analysis of variance for effects of farm scales and parity classes on milk fat yield of dairy cows in the urban and peri-urban centers of central rift valley, Oromia.

Sources	**df**	**SS**	**MS**	**F**	**p=**
Model	2	0.10785986	0.05392993	4.65	0.019
Farm scale	1	0.10488089	0.10488089	9.05	0.006
Parity classes	1	0.00297897	0.00297897	0.26	0.62
Error	25	0.28973434	0.01158937		
Total	28	0.39759420			
Coefficient of variation = 21.78					

Appendix Table 5 Analysis of variance for effects of farm scales and parity classes on milk protein content of dairy cows in the urban and peri-urban centers of central rift valley, Oromia.

Sources	**df**	**SS**	**MS**	**F**	**p=**
Model	2	0.01209286	0.00604643	0.06	0.95
Farm scale	1	0.0108357	0.0108357	0.10	0.75
Parity classes	1	0.00128929	0.00128929	0.01	0.91
Error	25	2.67331786	0.10693271		
Total	28	2.68541071			
Coefficient of variation = 11.58					

Appendix Table 6 Analysis of variance for effects of farm scales and parity classes on milk protein yield of dairy cows in the urban and peri-urban centers of central rift valley, Oromia.

Sources	**df**	**SS**	**MS**	**F**	**p=**
Model	2	0.09414314	0.04707157	5.57	0.01
Farm scale	1	0.09269809	0.09269809	10.97	0.003
Parity classes	1	0.00144505	0.00144505	0.17	0.68
Error	25	0.21116602	0.00844664		
Total	28	0.30530916			
Coefficient of variation = 23.92					

Appendix Table 7 Analysis of variance for effects of farm scales and parity classes on milk total solid content of dairy cows in the urban and peri-urban centers of central rift valley, Oromia.

Sources	df.	SS	MS	F	p=
Model	2	0.00928571	0.00464286	0.01	0.99
Farm scale	1	0.00035714	0.00035714	0.0	0.98
Parity classes	1	0.00892857	0.00892857	0.01	0.92
Error	25	2.02321429	0.80092857		
Total	28	20.0325			
Coefficient of variation = 7.94					

Appendix Table 8 Analysis of variance for effects of farm scales and parity classes on days from calving to first observed estrus of dairy cows in the urban and peri-urban centers of central rift valley, Oromia.

Sources	df.	SS	MS	F	P=
Model	2	2425.85714	1212.92857	0.42	0.66
Farm scale	1	2414.285714	2414.285714	0.83	0.37
Parity classes	1	11.571429	11.571429	0.00	0.95
Error	25	72521.00	2900.00		
Total	28	74946.85714			
Coefficient of variation = 51.09					

Appendix Table 9 Analysis of variance for effects of farm scales and parity classes on days open of dairy cows in the urban and peri-urban centers of central rift valley, Oromia.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	2	4028.7143	2014.3571	0.27	0.77
Farm scale	1	3657.142857	3657.142857	0.49	0.49
Parity classes	1	371.571429	371.571429	0.05	0.95
Error	25	186630.00	7465.02		
Total	28	190658.7143			
Coefficient of variation = 50.07					

Appendix Table 10 Analysis of variance for effects of farm scales and parity classes on the number of services per conception of dairy cows in the urban and peri-urban centers of central rift valley, Oromia.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	2	1.42857143	0.71428571	1.34	0.28
Farm scale	1	1.28571429	1.28571429	2.42	0.13
Parity classes	1	0.14285714	0.14285714	0.27	0.61
Error	25	13.28571429	0.53142857		
Total	28	14.71428571			
Coefficient of variation = 40.82					

Appendix Table 11 Relationship of dry matter intake to productive and reproductive traits of dairy cows under small and large scale farmer's management systems in Central Rift Valley of Oromia.

Regression	Equation	r^2	SE	p-value
Regression of DM intake on daily milk yield	Y=1.35 + 0.89x	0.46	2.56	0.001
Regression of DM intake on daily FC milk yield	Y=3.35 + 0.69x	0.36	2.47	0.001
Regression of DM intake on milk fat percentage	Y=4.62 – 0.07x	0.09	0.58	0.12
Regression of DM intake on milk fat yield	Y=0.18 + 0.02x	0.24	0.11	0.01
Regression of DM intake on milk protein percentage	Y=2.86 + 0.003x	-0.04	0.32	0.90
Regression of DM intake on milk protein yield	Y=0.05 + 0.02x	0.35	0.09	0.001
Regression of DM intake on total solid percentage	Y=12.11 – 0.06x	0.03	0.86	0.35
Regression of DM intake on days from calving to first estrus	Y=36.72 + 4.96x	0.06	52.02	0.20
Regression of DM intake on days open	Y=173.3 – 0.97x	0.04	85.60	0.88
Regression of DM intake on number of services per conception	Y=0.29 + 0.11x	0.15	0.69	0.04

<u>Appendix Table 12</u> Relationship of crude protein intake to productive and reproductive traits of dairy cows under small and large scale farmer's management systems in Central Rift Valley of Oromia.

Regression	**Equation**	r^2	**SE**	**p-value**
Regression of CP intake on daily milk yield	Y=5.2 + 0.004x	0.44	2.61	0.001
Regression of CP intake on daily FC milk yield	Y=5.85 + 0.003x	0.39	2.40	0.001
Regression of CP intake on milk fat percentage	Y=4.06 + 0.0002x	0.03	0.60	0.37
Regression of CP intake on milk fat yield	Y=0.25 + 0.0001x	0.30	0.10	0.01
Regression of CP intake on milk protein percentage	Y=2.91 + 4.18x	0.01	0.32	0.71
Regression of CP intake on milk protein yield	Y=0.15 + 0.0001x	0.36	0.09	0.001
Regression of CP intake on total solid percentage	Y=11.41 – 6.89x	0.00	0.88	0.83
Regression of CP intake on days from calving to first estrus	$Y=103.12 - 0.02x + 9.1x^2$	-0.03	53.36	0.52
Regression of CP intake on days open	$Y=386.22 - 0.24x + 5.7x^2$	-0.03	85.18	0.54
Regression of CP intake on number of services per conception	$Y=1.58 - 0.001x + 2.86x^2$	0.31	0.64	0.01

<u>Appendix Table 13</u> Relationship of dietary CP concentration to productive and reproductive traits of dairy cows under small and large scale farmer's management systems in Central Rift Valley of Oromia.

Regression	Equation	r^2	SE	p-value
Regression of CP% on daily milk yield	$Y=3.48 + 0.68x$	0.18	3.17	0.026
Regression of CP% on daily FC milk yield	$Y=4.74 + 0.54x$	0.15	2.85	0.044
Regression of CP% on milk fat percentage	$Y= - 2.89 + 0.95x – 0.03x^2$	0.10	0.59	0.26
Regression of CP% on milk fat yield	$Y=0.22 + 0.02x$	0.10	0.12	0.09
Regression of CP% on milk protein percentage	$Y=3.08 - 0.02x$	0.01	0.32	0.55
Regression of CP% on milk protein yield	$Y=0.13 + 0.02x$	0.12	0.10	0.07
Regression of CP% on total solid percentage	$Y= - 1.74 + 1.83x – 0.06x^2$	0.16	0.82	0.12
Regression of CP% on days from calving to first estrus	$Y=577.21 – 74.28x + 2.8x^2$	0.19	49.43	0.08
Regression of CP% on days open	$Y=1458.35-185.35x+6.46x^2$	0.18	78.99	0.08
Regression of CP% on the number of services per conception	$Y=7.86-0.98x+0.04x^2$	0.20	0.69	0.07

<u>Appendix Table 14</u> Relationship of dietary metabolizable energy intake to productive and reproductive traits of dairy cows under small and large scale farmer's management systems in Central Rift Valley of Oromia.

Regression	Equation	r^2	SE	p-value
Regression of ME intake (MJ/d) on daily milk yield	Y=2.88 + 0.08x	0.35	2.81	0.001
Regression of ME intake (MJ/d) on daily FC milk yield	Y=4.44 + 0.07x	0.28	2.62	0.01
Regression of ME intake (MJ/d) on milk fat percentage	Y=4.43 + 0.006x	0.06	0.59	0.22
Regression of ME intake (MJ/d) on milk fat yield	Y=0.22 + 0.002x	0.19	0.11	0.022
Regression of ME intake (MJ/d) on milk protein percentage	Y=3.01 – 0.002x	0.01	0.32	0.57
Regression of ME intake (MJ/d) on milk protein yield	Y=0.09 + 0.002x	0.27	0.09	0.01
Regression of ME intake (MJ/d) on total solid percentage	Y=11.76 + 0.004x	0.02	0.88	0.75
Regression of ME intake (MJ/d) on days from calving to first estrus	Y=86.76 + 0.15x	-0.03	53.57	0.73
Regression of ME intake (MJ/d) on days open	Y=12.5 + 0.27x	-0.03	85.37	0.69
Regression of ME intake (MJ/d) on the number of services per conception	Y= - 0.35 + 0.02x	0.30	0.63	0.002

<u>Appendix Table 15</u> Relationship of dietary neutral detergent fiber concentration (%DMI) to productive and reproductive traits of dairy cows under small and large scale farmers' management systems in Central Rift Valley of Oromia.

Regression	Equation	r^2	SE	p-value
Regression of NDF% on daily milk yield	$Y= - 15.68 +1.2x-0.01x^2$	0.15	3.28	0.12
Regression of NDF% on daily FC milk yield	$Y= - 17.04 +1.2x – 001x^2$	0.21	2.79	0.05
Regression of NDF% on milk fat percentage	Y=3.52 + 0.003x	- 0.04	0.61	0.81
Regression of NDF% NDF% on milk fat yield	$Y= - 0.72+0.05x-0.000x^2$	0.22	0.11	0.04
Regression of NDF% on milk protein percentage	Y=2.5 + 0.007x	0.03	0.32	0.35
Regression of NDF% on milk protein yield	$Y= - 0.38+0.03x-0.0003x^2$	0.13	0.10	0.17
Regression of NDF% on total solid percentage	$Y= 7.38+0.16x-0.002x^2$	0.04	0.88	0.61
Regression of NDF% on days from calving to first estrus	Y=38.02 +1.42x	0.05	52.21	0.23
Regression of NDF% on days open	Y=158.49 + 0.03x	0.00	85.63	0.99
Regression of NDF% NDF% on the number of services per conception	$Y= - 2.91+0.21x-0.002x^2$	0.09	0.73	0.30

Appendix Table 16 Relationship of dietary ether extract concentration (%DMI) to productive and reproductive traits of dairy cows under small and large scale farmers' management systems in Central Rift Valley of Oromia.

Regression	Equation	r^2	SE	p-value
Regression of EE% on daily milk yield	$Y= - 6.34+12.74x - 1.92x^2$	0.26	3.05	0.02
Regression of EE% on daily FC milk yield	$Y= - 9.08+13.66x – 2.02x^2$	0.32	2.59	0.01
Regression of EE% on milk fat percentage	$Y=1.85 + 0.91x - 0.12x^2$	- 0.07	0.62	0.90
Regression of EE% NDF% on milk fat yield	$Y= - 0.44 + 0.57x – 0.08x^2$	0.31	0.11	0.01
Regression of EE% on milk protein percentage	Y= 2.96 – 0.04x	0.01	0.32	0.71
Regression of EE% on milk protein yield	$Y= - 0.13 + 0.34x – 0.05x^2$	0.24	0.10	0.04
Regression of EE% on total solid percentage	Y= 11.65 + 0.10x	0.01	0.87	0.70
Regression of EE% on days from calving to first estrus	$Y=-540.9+351.9x– 46.50x^2$	0.19	49.26	0.07
Regression of EE% on days open	$Y=-440+308.9x-38.64x^2$	0.05	85.34	0.56
Regression of EE% NDF% on the number of services per conception	Y=- 4.91 +3.65x – 0.48x2	0.11	0.73	0.25

<u>Appendix Table 17</u> Relationship of dietary calcium concentration (%DMI) to productive and reproductive traits of dairy cows under small and large scale farmers' management systems in Central Rift Valley of Oromia.

Regression	Equation	r^2	SE	p-value
Regression of Ca% on daily milk yield	Y= 6.11 + 18.02x	0.17	3.18	0.03
Regression of Ca% on daily FC milk yield	Y= 8.32 + 10.96x	0.08	2.96	0.15
Regression of Ca% on milk fat percentage	$Y= - 4.74+43.35x- 53.77x^2$	0.31	0.52	0.01
Regression of Ca% NDF% on milk fat yield	Y=0.39 + 0.26x	0.03	0.12	0.40
Regression of EE% on milk protein percentage	$Y=0.11+14.24x – 17.96x^2$	0.15	0.30	0.12
Regression of EE% on milk protein yield	Y=0.23 + 0.36x	0.07	0.11	0.18
Regression of EE% on total solid percentage	$Y=- 0.35+58.3x-70.6x^2$	0.20	0.80	0.06
Regression of EE% on days from calving to first estrus	$Y=690.3- 2926x+3535x^2$	0.13	51.10	0.17
Regression of EE% on days open	$Y=866.2 – 3573x +4361x^2$	0.09	83.47	0.32
Regression of EE% NDF% on the number of services per conception	Y=0.13 + 3.99x	0.18	0.68	0.03

<u>Appendix Table 18</u> Relationship of dietary phosphorus concentration (%DMI) to productive and reproductive traits of dairy cows under small and large scale farmers' management systems in Central Rift Valley of Oromia.

Regression	Equation	r^2	SE	p-value
Regression of P% on daily milk yield	Y=6.30 + 11.79x	0.47	2.54	0.001
Regression of P% on daily FC milk yield	Y=6.52 + 10.25x	0.46	2.27	0.001
Regression of P% on milk fat percentage	$Y=1.90+6.60x-5.5x^2$	0.09	0.59	0.30
Regression of P% NDF% on milk fat yield	Y=0.27 + 0.37x	0.37	0.10	0.001
Regression of P% on milk protein percentage	Y=2.88 – 0.09x	0.00	0.32	0.78
Regression of P% on milk protein yield	Y=0.18 + 0.32x	0.37	0.09	0.001
Regression of P% on total solid percentage	$Y=7.06+14.44x-11.2x^2$	0.16	0.82	0.12
Regression of P% on days from calving to first estrus	$Y=199.1-432x+412x^2$	0.17	49.83	0.09
Regression of P% on days open	$Y=630.97-1645.7x+1299x^2$	0.22	77.26	0.05
Regression of P% on the number of services per conception	$Y=3.08-6.5x+6.5x^2$	0.28	0.65	0.02

Appendix Table 19 Analysis of variance for hay dry matter intake of lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole soil.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	3.12125815	0.78031454	3.22	0.03
Treatment	3	2.76315134	0.92105045	3.80	0.02
Block (Calving time)	1	0.34873386	0.34873386	1.44	0.24
Error	26	6.30893873	0.24265149		
Total	30	9.43019688			
Coefficient of variation = 8.07					

Appendix Table 20 Analysis of variance for supplements dry matter intake of lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole soil.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	37.88158502	9.4703963	4.15	0.01
Treatment	3	1.28765279	0.4292176	0.19	0.90
Block (Calving time)	1	36.39775560	36.39775560	15.95	0.001
Error	26	59.31493435	2.28134363		
Total	30	97.19651937			
Coefficient of variation = 17.87					

Appendix Table 21 Analysis of variance for total dry matter intake of lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole soil.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	34.4272495	8.6068124	3.04	0.04
Treatment	3	4.71524813	1.57174938	0.56	0.65
Block (Calving time)	1	29.62100570	29.62100570	10.47	0.01
Error	26	73.5827651	2.8301064		
Total	30	108.0100146			
Coefficient of variation = 11.56					

Appendix Table 22 Analysis of variance for total crude protein intake of lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole soil.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	1981919.56	495479.89	4.73	0.01
Treatment	3	402460.519	134153.506	1.28	0.30
Block (Calving time)	1	1536906.134	1536906.134	14.68	0.001
Error	26	2722059.589	104694.60		
Total	30	4703979.148			
Coefficient of variation = 15.61					

Appendix Table 23 Analysis of variance for crude protein concentration (%DMI) of lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole soil.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	20.95332701	5.23833175	9.09	0.001
Treatment	3	9.26061443	3.08687148	5.36	0.01
Block (Calving time)	1	10.99865099	10.99865099	19.09	0.01
Error	26	14.97940194	0.57613084		
Total	30	35.9.3272895			
Coefficient of variation = 5.37					

Appendix Table 24 Analysis of variance for metabolizable energy intake (MJ/d) of lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole soil.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	3531.29985	882.82496	3.14	0.03
Treatment	3	221.196679	73.732226	0.26	0.85
Block (Calving time)	1	3360.302319	3360.302319	11.93	0.01
Error	26	7320.68605	281.56485		
Total	30	10851.98590			
Coefficient of variation = 12.65					

<u>Appendix Table 25</u> Analysis of variance for neutral detergent fiber (NDF) concentration (%DMI) of lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	356.8572816	89.2143204	43.52	0.001
Treatment	3	326.3202215	108.7734072	53.06	0.001
Block (Calving time)	1	36.4903352	36.4903352	17.80	0.001
Error	26	53.3015589	2.0500600		
Total	30	410.1588404			
Coefficient of variation = 2.64					

<u>Appendix Table 26</u> Analysis of variance for ether extract (EE) concentration (%DMI) of lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole soil.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	6.38960799	1.59740200	38.38	0.001
Treatment	3	5.45264083	1.81754694	43.67	0.001
Block (Calving time)	1	0.76432917	0.76432917	18.37	0.001
Error	26	1.08207491	0.04161827		
Total	30	7.47168291			
Coefficient of variation = 5.76					

Appendix Table 27 Analysis of variance for dietary non fibrous carbohydrate (NFC) concentration (%DMI) of lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	446.3728920	111.5932230	17.04	0.001
Treatment	3	431.1498637	143.7166212	21.95	0.001
Block (Calving time)	1	18.8153615	18.8153615	2.87	0.10
Error	26	170.2642008	6.5486231		
Total	30	616.6370927			
Coefficient of variation = 14.44					

Appendix Table 28 Analysis of variance of dietary calcium (Ca) concentration (%DMI) for lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	1.88262159	0.47065540	239.77	0.001
Treatment	3	1.87247100	0.62415700	317.97	0.001
Block (Calving time)	1	0.02224081	0.02224081	11.33	0.01
Error	26	0.05103610	0.00196293		
Total	30	1.93365769			
Coefficient of variation = 5.12					

Appendix Table 29 Analysis of variance of dietary phosphorus (P) concentration (%DMI) for lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole soil.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	0.03737725	0.00934431	9.58	0.001
Treatment	3	0.01963643	0.00654548	6.71	0.01
Block (Calving time)	1	0.01781133	0.01781133	18.27	0.001
Error	26	0.02535070	0.00097503		
Total	30	0.06272795			
Coefficient of variation = 5.71					

Appendix Table 30 Analysis of variance of the dietary ratio of calcium to phosphorus (Ca: P) for lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	df.	SS	MS	F	P=
Model	4	5.33927026	1.33481757	1830.02	0.001
Treatment	3	5.30483289	1.76827763	2424.29	0.001
Block (Calving time)	1	0.00988355	0.00988355	13.55	0.001
Error	26	0.01896438	0.00072940		
Total	30	5.35823464			
Coefficient of variation = 1.71					

Appendix Table 31 Analysis of variance of dietary sodium (Na) concentration (%DMI) for lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	1.36794343	0.34198586	276.51	0.001
Treatment	3	1.35640286	0.45213429	365.57	0.001
Block (Calving time)	1	0.02072726	0.02072726	16.76	0.001
Error	26	0.03215635	0.00123678		
Total	30	1.40009978			
Coefficient of variation = 7.45					

Appendix Table 32 Analysis of variance of dietary potassium (K) concentration (%DMI) for lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	0.04980280	0.012450070	44.92	0.001
Treatment	3	0.04614376	0.01538125	55.50	0.001
Block (Calving time)	1	0.00496333	0.00496333	17.91	0.001
Error	26	0.030720611	0.00027716		
Total	30	0.05700891			
Coefficient of variation = 1.31					

<u>Appendix Table 33</u> Analysis of variance of dietary magnesium (Mg) concentration (%DMI) for lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	0.00406489	0.00101622	9.19	0.001
Treatment	3	0.00211763	0.00070588	6.38	0.01
Block (Calving time)	1	0.00203516	0.00203516	18.40	0.001
Error	26	0.00287637	0.00011063		
Total	30	0.00694126			
Coefficient of variation = 3.55					

<u>Appendix Table 34</u> Analysis of variance of kg milk yield per kg dietary concentrate supplement intake for lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	0.80678300	0.20169575	3.33	0.03
Treatment	3	0.78337710	0.26112570	4.31	0.014
Block (Calving time)	1	0.03388952	0.03388952	0.56	0.46
Error	26	1.57589983	0.06061153		
Total	30	2.38268283			
Coefficient of variation = 12.00					

<u>Appendix Table 35</u> Analysis of variance of kg milk yield per kg of total dry matter intake by lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	0.42242445	0.10560611	3.82	0.02
Treatment	3	0.1807338	0.06029113	2.18	0.11
Block (Calving time)	1	0.25860240	0.25860240	9.37	0.01
Error	26	0.71787820	0.02761070		
Total	30	1.14030265			
Coefficient of variation = 14.10					

<u>Appendix Table 36</u> Analysis of variance of supplement costs per kg of milk yield by lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	0.06788523	0.01697131	4.52	0.01
Treatment	3	0.06649594	0.02226531	5.91	0.003
Block (Calving time)	1	0.00229167	0.00229167	0.61	0.44
Error	26	0.09756956	0.00375268		
Total	30	0.16545478			
Coefficient of variation = 12.03					

Appendix Table 37 Analysis of variance of daily milk yield by lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	207.9490024	51.9872506	4.20	0.01
Treatment	3	41.4926687	13.8308896	1.12	0.36
Block (Calving time)	1	169.2623625	169.2623625	13.66	0.001
Error	26	322.1964750	12.3921721		
Total	30	530.1454774			
Coefficient of variation = 20.96					

Appendix Table 38 Analysis of variance of fat corrected milk yield by lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	268.8210251	67.2052563	5.05	0.01
Treatment	3	67.5318978	22.5106326	1.69	0.19
Block (Calving time)	1	203.2800000	203.2800000	15.27	0.001
Error	26	346.1977481	13.3152980		
Total	30	615.0187732			
Coefficient of variation = 22.5					

Appendix Table 39 Analysis of variance of milk fat content of lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	1.51273522	0.37818380	4.14	0.01
Treatment	3	0.93696875	0.31232292	3.42	0.03
Block (Calving time)	1	0.55430060	0.55430060	6.06	0.02
Error	26	2.37645833	0.09140224		
Total	30	3.88919355			
Coefficient of variation = 8.11					

Appendix Table 40 Analysis of variance of milk fat yield by lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	0.50594052	0.12648513	5.41	0.003
Treatment	3	0.14378357	0.04792786	2.05	0.13
Block (Calving time)	1	0.36430035	0.36430035	15.57	0.001
Error	26	0.60833779	0.02339761		
Total	30	1.11427831			
Coefficient of variation = 24.15					

Appendix Table 41 Analysis of variance of milk protein content of lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	0.04579889	0.01144972	0.29	0.88
Treatment	3	0.02872727	0.00957576	0.25	0.86
Block (Calving time)	1	0.01627090	0.01627090	0.42	0.52
Error	26	1.01003981	0.03884769		
Total	30	1.05583871			
Coefficient of variation = 7.9					

Appendix Table 42 Analysis of variance of milk protein yield by lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	0.14840718	0.03710179	3.99	0.01
Treatment	3	0.02598088	0.00866029	0.93	0.44
Block (Calving time)	1	0.12383710	0.123833710	13.31	0.01
Error	26	0.24193150	0.00930506		
Total	30	0.39033867			
Coefficient of variation = 22.97					

Appendix Table 43 Analysis of variance of milk total solid content by lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	0.92808169	0.23202042	0.38	0.82
Treatment	3	0.92356019	0.30785340	0.51	0.68
Block (Calving time)	1	0.00698578	0.00698578	0.01	0.92
Error	26	15.68627315	0.60331820		
Total	30	16.61435484			
Coefficient of variation = 6.89					

Appendix Table 44 Analysis of variance of days from calving to first estrus by lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	1065.23419	266.30855	0.15	0.96
Treatment	3	1052.413473	350.804491	0.20	0.89
Block (Calving time)	1	1.219243	1.219243	0.00	0.98
Error	26	38387.28433	1744.87656		
Total	30	39452.51852			
Coefficient of variation = 54.00					

<u>Appendix Table 45</u> Analysis of variance of days open by lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	12820.38444	3205.09611	0.98	0.44
Treatment	3	12474.34943	4158.11648	1.27	0.31
Block (Calving time)	1	999.25520	999.25520	0.30	0.59
Error	26	72234.13408	3283.36973		
Total	30	85054.51852			
Coefficient of variation = 52.3					

<u>Appendix Table 46</u> Analysis of variance of number of services per conception by lactating dairy cows fed hay and concentrate supplement with/without cottonseed cake and/or bole.

Sources	**df.**	**SS**	**MS**	**F**	**p=**
Model	4	2.72429187	0.68107297	0.64	0.63
Treatment	3	1.07594022	0.35864674	0.34	0.80
Block (Calving time)	1	1.97072044	1.97072044	1.86	0.19
Error	26	23.27570813	1.05798673		
Total	30	26.00000			
Coefficient of variation = 61.7					

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