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Aims and Scope: The Ethiopian Journal of Animal Production is a peer reviewed journal publishing original basic and applied research articles, short communications, technical notes, review articles dealing with livestock and livestock related issues. Although the journal focuses on livestock production in Ethiopia, papers from similar agro-ecological regions of the world are welcomed.

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Evaluation of different strains of mulberry silkworms /*Bombyx mori* L. / for their adaptability and silk yield in Ethiopia

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Abstract

Mulberry silkworm, Bomyx mori L. is one of the silkworms under utilization in Ethiopia. However, rearing of selected strains of this mulberry silkworm race that adapt to different agro-ecologies is very essential for improving silk cocoon quality, yield and profitability. In this experiment, four Kenyan (ICIPE) bivoltine races (Kenya-1, Kenya-3, Kenya-4 and Kenya-5), two Korean bivoltine races (Korea-1 and Korea-3), two Vietnamese multivoltine (Mult-yel and Mult-wh) mulberry silkworm strains were evaluated in different locations (Melkassa, Alagae, Wondo-Genet and Jimma) which represent different agro-ecologies of Ethiopia. The experiment was laid out in Completely Randomized Design (CRD) in three replications. Thus, different silkworm strains showed statistical significant silkworm characteristic ranges in different locations which include egg hatchability (63.67% to 91.00%), larval duration (21.67days to 32.00 days), total life cycle duration (44.94 days to 79.67 days), single weight of larva (1.328 grams to 3.567 grams), effective rate of rearing (56.22% to 92.0%), single cocoon weight (0.726 grams to 1.600 grams), single shell weight (0.108 grams to 0.355 grams) and silk ratio (14.71 to 22.76%). However, a bivoltine mulberry silkworm strain known by Kenya 1 (ICIPE1) have showed an outstanding performance compared to other strains in all locations especially in cocoon parameters. Therefore, it is recommended for future research and development efforts on mulberry sericulture in Ethiopia.

Key words: *mulberry, silkworm, strains, performance, cocoon*

Introduction

The silkworm, *Bombyx mori* L spins valuable silk fibre, making it one of the most beneficial insects to mankind, and is becoming an attractive multifunctional material for both textile and non-textile uses (Murthy *et al*, 2013).The practice of silk production involves diverse activities from the cultivation of host plants to silk processing, which engage people of all spectrums. Further, the by-products also find uses ranging from fertilizers in rural areas to pharmaceutical industries (Legay, 1958).Thus, silk production has the potential to make a significant contribution to the economy of many countries where there is surplus labor, low-costs of production and a willingness to adopt new technologies (Hajare *et al*., 2007).

In Ethiopia, silk has strong attraction to the people starting from early period of Axum Kingdom. However, the silk yarns used were imported from India, Arabia and China **(**Spring and Hudson, 2002**).** Currently, Ethiopia is the second populous country in Africa after Nigeria. There is a general trend of increasing rate of unemployment in the country. Therefore, sericulture, which is an agro based labor intensive and environment friendly cottage industry, can be an efficient and effective agricultural endeavor for the country. The business holds a ray of hope at village level for Ethiopian citizen migrating to cities searching for jobs **(**Kedir *et al*., 2014**)**. As a result, silk production from mulberry silkworm is practiced bits in bits in different parts of the country **(**Metaferia *et al*., 2006**).**

However, rearing of superior silkworm strains that well adapt to the local environment is an important method for enhancing cocoon quality, increasing cocoon yield an improving economic benefit **(**Nguku *et al*., 2009**)**. Differences in agro-ecologies across regions including significant distinctions in temperature and humidity require a type of silkworm strain which is both hyper silkgeneous and adversity resistant (Basavaraja *et al*, 2005). Rearing performance in silkworms is also affected by ecological, biochemical, physiological and quantitative characters, which influence growth and development, quantity and quality of silk they produce in different geographical locations (Virk *et al*, 2011; Ramesh *et al*, 2012; Anandakumar and Michael, 2012 and Reddy *et al*, 2012). The success in silkworm rearing depends on the various factors including successful implementation of technological and managerial tools along with high yielding and best-suited mulberry varieties and silkworm strains (Rajan and Himantharaj, 2005). In addition, the *B. mori* insect is an oligophagous herbivore and depends mainly on the quality of mulberry leaves and environmental conditions for its development (Murthy *et al*, 2007).

Performance of the strain itself in a given environment indicates its superiority. During evaluation, emphasis was given on the phenotypic expression of traits of economic importance under different temperature conditions. However, as the objective of the study was for greater viability and high productivity merits, equal importance was given on these two traits during selection of parents. The significant variations observed in the phenotypic manifestation for the traits analyzed can be attributed to the genetic constitution of the breeds and their degree of expression to which they are exposed during their rearing. Such variations in the manifestation of phenotypic traits of the breeds studied can be ascribed to the influence of environmental conditions. Variable gene frequencies at different loci make them to respond differently. The results are in line with the findings of Sudhakar *et al,* 2001.

Therefore, appropriate selection of the silkworms strains based on rearing performance and economic qualities in different climatic conditions is essential to select and exploit suitable silkworm strains for improved sericulture practices (Basavaraja *et al*, 2005 and Virk *et al*, 2011). On the other hand, there is no any recommended silkworm strain for mulberry silk production in Ethiopia. Hence, this experiment was initiated with objective of introducing and evaluating different mulberry silkworm strains for their adaptability, better yield and quality silk.

Materials and Methods

Description of the Study Areas

The experiment was conducted in four locations: Melkassa, Wondo-Genet and Jimma Agricultural Research Centers and Algae Agricultural Technical, Vocational, Educational and Training (ATVET) College, Ethiopia. These locations represent some of the agro-ecologies of the country assumed suitable for silkworm development and productivity.

Melkassa Agricultural Research Center (MARC), Central Rift Valley of Ethiopia, which is located at the distance of 15 km in the southeasterly direction from Adama town, which is situated at 8^{o} 24' N latitude and 39^{o}21' E longitude with an altitude of 1550 meters above sea level (MoA, 2000). The main rainy season for this area is from June to September (Kiremt) which contributes about 69% of the total annual rainfall and the second short rainy season (Belg) is from March to May which brings nearly 24% of the precipitation. The third season, which is from October to January (Bega), is dry most of the time but contributes around 7% of the total annual rainfall especially during October and January for the late cessation of Kiremt and early onset of Belg seasons, respectively. For the period 1977-2006, the annual average rainfall was 702 mm and ranged from 450 to 918 mm. The peak months were July and August with an average rainfall of 157.5 and 161.6 mm, respectively. The long-term mean rainfall for the Bega, Belg and Kiremt seasons was 52, 166 and 482.5 mm, respectively. For the period 1977-2006, the daily mean maximum and minimum temperatures were 28.5 and 13.8 °C, respectively. The mean maximum temperature was between 30.9 °C during May and 26.2 °C during August (Gebru and Abebe, 2011). According to the recent agro-ecological classification of Ethiopia (MoA, 2000), the Melkassa Hypo Calcic Regosol ecotope falls in the zone termed hot to warm semiarid lowlands.

Jimma Research center (JARC) which is found at about 345 km from Addis Ababa in South west and lies between 36° 10´ E longitude and 7° 40´ N latitude. This area experiences annual average rainfall of 1000 mm for 8 to 10 months. The zone has an elevation ranging from 880 to 3360 masl. The temperature of Jimma zone varies from 8-28°C. The average annual temperature is 20°C (Haile A. and Tolemariam T, 2008).

Wondo-Genet Agricultural Research Center located at 7° 192′ N latitude and 38° 382′ E longitudes with an altitude of 1780 m above mean sea level. The site receives a mean annual rainfall of 1000 mm with minimum and maximum temperatures of 10 and 30°C, respectively. The soil textural class is clay loam with an average pH of 7.2 (Tesfaye, 2005 - unpublished).

Lay out and rearing

As per the rearing recommendations of silkworms by Rajan and Himantharaj (2005), the silkworm rearing room and equipments were cleaned, washed and disinfected with 2% formalin solution at the rate of 800ml per 10m^2 before the commencement of the experiment (rearing).Under this experiment, eight mulberry silkworm strains were considered as treatments. These include four Kenyan (ICIPE) bivoltine strains (Kenya-1, Kenya-3, Kenya-4 and Kenya-5), two Korean bivoltine strains (Korea-1 and Korea-3) and two Vietnamese multivoltine strains (Mult-yel and Mult-wh).The experiment was designed in a Completely Randomized Design (CRD) and the treatments were replicated three times. In each replication, 200 worms were used and allowed to complete their life cycle. Rearing was done in trays measuring 90 x 60cm, placed on rearing racks, 150 x 75 x 200cm that could hold 20 trays each and for every feeding tray equal amount of feeds from same feed plant variety were given. Mulberry (*Bomyx mori*) was cultivated and used as feed source for these silkworms. Tender leaves were fed four times a day until the larvae ends II instar stage and semi tender leaves to III instar larvae, while more matured leaves were fed to IV and V instar larvae.

Data Collection and Analysis

As adopted by Kedir *et al.* (2014), egg count was made before larval hatching. On the sixth day of spinning, the cocoons were harvested, counted and weighed. Data like larval and total life cycle duration (in days) and mature larval weight (in grams) were recorded. Cocoons from all strains were harvested from the mountages and then sorted. Cocoons were weighed using sensitive electronic balance after cutting open the cocoons using a blade to release the pupa and the moulted skin. Then, the cocoon weight (with pupa) and cocoon shell weight (without pupa) were documented. The following formulae were used for analysis of egg hatchability (%), effective rate of rearing (ERR %) and silk or shell ratio (%) calculations.

$$Egg\ hatchability\ to\ larva = \frac{Number\ of\ normal\ eggs - Number\ of\ nonhatched\ eggs}{Number\ of\ normal\ eggs}$$

$$Shell\ ratio = \frac{weight\ of\ the\ cocoon\ shell}{weight\ of\ the\ whole\ cocoon} x\ 100$$

$$ERR = \frac{Number\ of\ cocoon\ yield}{Number\ of\ larvae\ brushed} x100$$

Finally, data were analyzed using SAS software at 5% level of significance (SAS, 2000). Significant means ($p<0.05$) were separated using Least Significant Difference (LSD).

Results

The present study clearly depicted variations in respect of growth and cocoon characters of mulberry silkworm strains, *Bombyx mori*. Data on growth, rearing performance and cocoon traits of mulberry silkworm strains *viz.*, egg hatchability (%), larval and total life cycle durations (days), larval weight (g), effective rate of rearing (%), cocoon weight (g), shell weight (g) and shell ratio (%) of different strains are illustrated below. In this experiment, significant differences were observed on silkworm characters among mulberry silkworm strains in different locations. Larval development periods and total life cycle durations variations were recorded among the different strains. The temperature and humidity records of the study areas are also presented in the table below (table 1).

Table 1. Temperature and humidity records of the study areas during experimental period

Study areas	Temperature			Humidity		
	Min	Max	Mean	Min	Max	Mean
Melkassa	19	34	27.6	25	76	58.1
Wondogenet	20	28	24.5	35	80	62.3
Jimma	18	32	25.8	41	83	67.6
Alage	22	32	27.1	30	78	60.4

Egg Hatchability: egg hatchability of mulberry silkworm strains to larval stage was ranging from 63.67% to 91.0% (Table 2). Statistically significant variation in mean egg hatchability among mulberry silkworm strains was observed in Melkassa and Jimma areas. In Melkassa, Mult-yel and Kenya-1strains showed highest egg hatchability (85.557 % and 84.997 %, respectively) but Kenya-3 strain showed the least one (63.67%). In Jimma, the best egg hatchability was achieved from Korea-3 (91.0%) followed by Korea-1 (89.0 %), Mult-wh (85.81 %), Kenya-1 (84.0 %) and Mult-yel (79.89 %) but the least hatchability was recorded from Kenya-4 (76%) (Table 2).

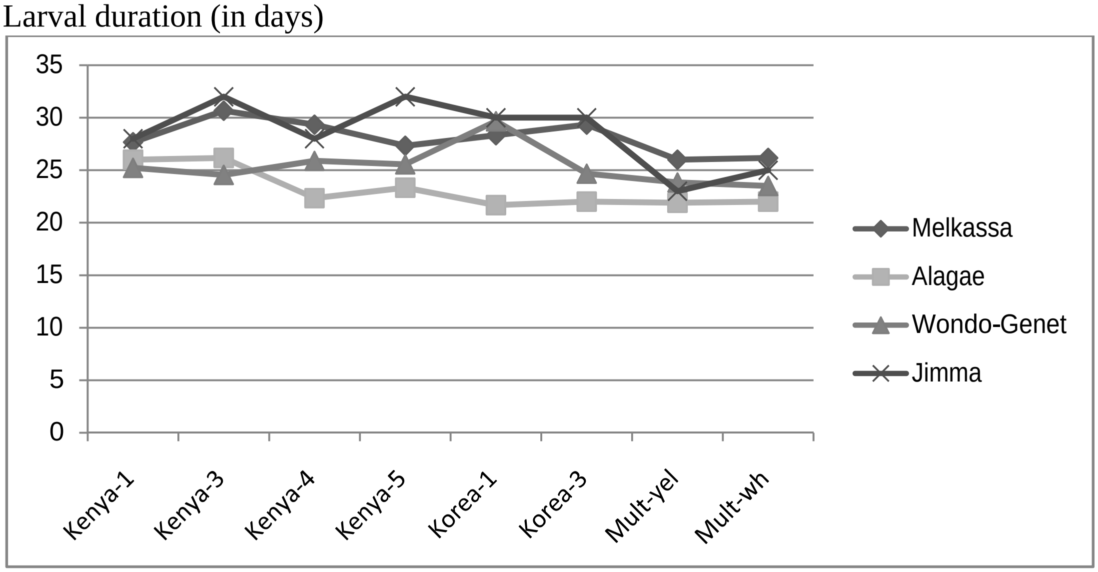
Table 2: Variations in egg hatchability among mulberry silkworm strains

Treatments	Melkassa	Alage	Wondo-Genet	Jimma
Kenya-1	84.997 [a]	88.333 [a]	86.556 [a]	84.000[abc]
Kenya-3	63.670 [c]	87.667 [a]	83.889 [a]	77.000 [c]
Kenya-4	66.557[bc]	88.553 [a]	84.222 [a]	76.000 [c]
Kenya-5	74.110 [b]	90.000 [a]	84.889 [a]	77.000 [c]
Korea-1	69.223[bc]	90.500 [a]	87.333 [a]	89.000[ba]
Korea-3	70.223[bc]	86.333 [a]	85.000 [a]	91.000 [a]
Mult-yel	85.557[a]	87.887 [a]	84.556 [a]	79.890[bc]
Mult-wh	72.333[bc]	85.777 [a]	86.222 [a]	85.813[bac]
Pr	0.004	0.7204	0.4086	0.0445
CV	6.8563	3.99333	2.37206	7.045656

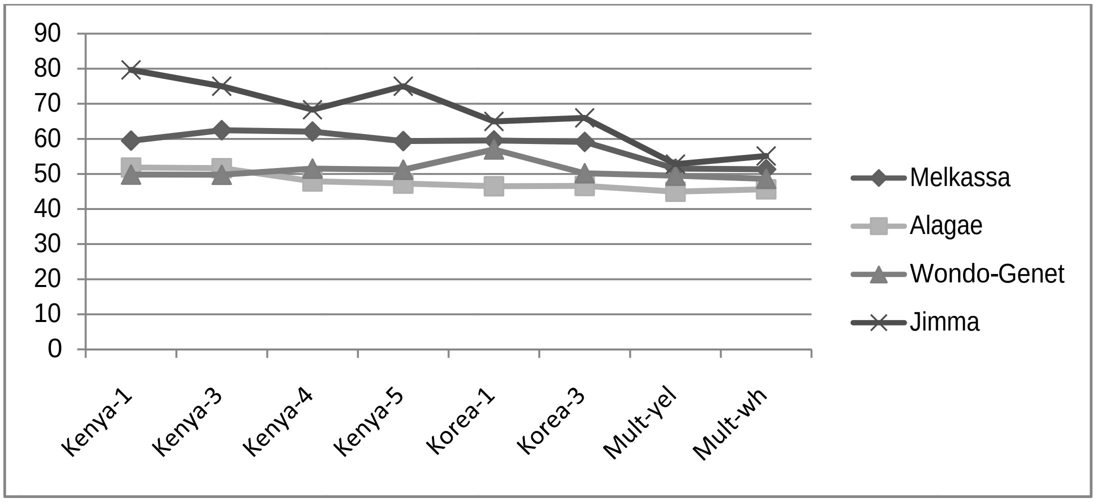
Means followed by the same letter within a column are not significantly different from each other at 5% level of probability.

Larval and total life cycle duration: Larval period and total life cycle duration of the strains revealed statistically significant difference among each other in all locations (Fig. 1). The shortest larval duration was noticed in Alagae from Mult-yel (21.89 days) and Mult-wh (22.0 days) strain. However, the longest larval duration was observed in Jimma from Kenya-5 (32.0 days) strain. In addition, the shortest total life cycle duration was seen in Alagae from Mult-yel (44.94 days) and Mult-wh (45.61 days) strains but the longest was in Jimma from Kenya-1 (79.67 days) strain. Generally, multivoltine strains revealed shorter larval and total life cycle durations compared to bivoltine strains (Fig 1).

a) Larval duration (in days)



b) Duration of the total life cycle (in days)



.Fig1. Larval (Fig. a) and total life cycle (Fig.b) (in days) duration of different mulberry silkworm strains

ERR (%): The experiment revealed a range of ERR (Effective Rate of Rearing) where lowest ERR was obtained in Alagae from Korea-3 strain (54.17 % and highest ERR was recorded from Mult-yel (92.0 %) and Mult-wh (92.0 %) (Fig. 2). Multivoltine mulberry silkworm strains (Mult-yel and Mult-wh) have better or at par ERR with other bivoltine strains in Melkassa and Wondo-Genet. The reverse was true in Alagae and Jimma areas. However, strain s named Kenya-1 and Kenya-5were doing well in regard to ERR (≥ 70%) consistently in all locations compared to other strains.

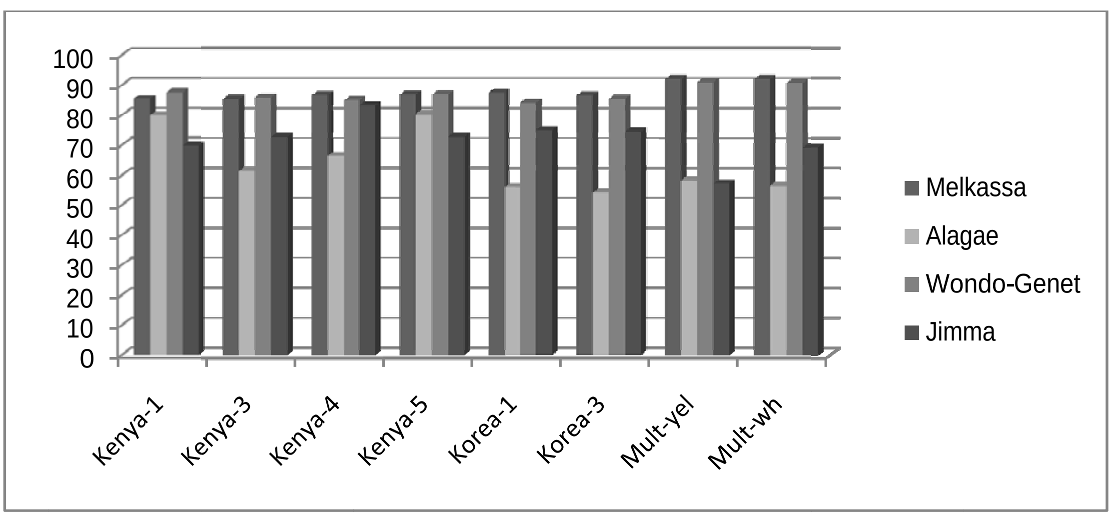


Fig 2. Variability of different mulberry silkworm strains in effective rate of rearing

Matured Larval Weight: Weight of a single matured silkworm larva was significantly different among mulberry silkworm strains in all locations (Table 3). In general, larval weight of bivoltine strains was higher than multivoltine strains in all areas. Among the strains, the highest larval weight (3.53 gram) was obtained from Kenya-1 strain in Melkassa area. This strain also exhibited better larval weights in all locations compared to other strains. However, the least larval weight (1.33grams) was recorded from Mult-yel strain in Wondo-Genet area (Table 3).

Table 3: Variations in larval weight (in grams) of different mulberry silkworm strains

Treatment	Melkassa	Alagae	Wondo-Genet	Jimma
Kenya-1	3.5333 ^{a}	2.11667 ^{a}	2.65667 ^{a}	3.2300 ^{a}
Kenya-3	3.100 ^{bc}	2.10000 ^{a}	2.03333 ^{b}	3.4233 ^{a}
Kenya-4	2.9200 ^{c}	1.78867 ^{b}	2.06667 ^{b}	3.5667 ^{a}
Kenya-5	3.1633 ^{bc}	1.63333 ^{c}	2.64333 ^{a}	3.5267 ^{a}
Korea-1	3.1767 ^{bc}	1.66667 ^{c}	1.97667 ^{b}	3.1433 ^{a}
Korea-3	3.4100 ^{ba}	1.60000 ^{c}	2.02222 ^{b}	3.4233 ^{a}
Mult-yel	2.2167 ^{d}	1.43333 ^{d}	1.37667 ^{c}	2.0867 ^{b}
Mult-wh	2.2033 ^{d}	1.40000 ^{d}	1.32833 ^{c}	2.2523 ^{b}
Pr	<0.0001	<.0001	<.0001	0.0071
CV	6.2904	3.384016	5.813441	10.85261

Means followed by the same letter within a column are not significantly different from each other at 5% level of probability

Cocoon Traits: With respect to cocoon traits (cocoon weight, shell weight and shell or silk ratio), there was statistically significant difference among silkworm strains in all locations (Table 4). In general, better cocoon traits were recorded from bivoltine strains compared to multivoltine ones. In specific terms, highest cocoon weight of 1.60 grams and 1.5747 grams was obtained from Kenya-1strain in Jimma and Melkassa areas, respectively. However, the lowest cocoon weight was obtained from Mult-yel (0.7289 grams) and Mult-wh (0.7256 grams) strains in Wondo-Genet area. Similarly, maximum shell weight was obtained from Kenya-1 strain in Jimma (0.3547 grams) and Melkassa (0.330 grams) areas but the minimum was from Mult-yel (0.1111 grams) and Mult-wh (0.1078 grams) strain in Wondo-Genet area. Moreover, best shell ratio was documented from Kenya-1 strain train in Jimma (22.152 %) and in Wondo-Genet (21.583 %) areas but the least was from Mult-yel and Mult-wh strain in all locations (Table 4).

Table 4: Differences in cocoon traits among mulberry silkworm strains

Treatments	Melkassa			Alage			Wondo-Genet			Jimma		
	Single cocoon weight (gram)	Single shell weight (gram)	Silk ratio (%)	Single cocoon weight (gram)	Single shell weight (gram)	Silk ratio (%)	Single cocoon weight (gram)	Single shell weight (gram)	Silk ratio (%)	Single cocoon weight (gram)	Single shell weight (gram)	Silk ratio (%)
Kenya-1	1.57467[a]	0.3300 [a]	20.9939[a]	1.18667 [a]	0.27000 [a]	22.7579 [a]	1.23556 [a]	0.26667 [a]	21.5829 [a]	1.60000 [a]	0.35467 [a]	22.152 [a]
Kenya-3	1.3800[bc]	0.2833[b]	20.5337 [a]	1.17667 [a]	0.26333 [a]	22.3837[b] [a]	1.21889 [a]	0.25000 [b]	20.5094[ba]	1.34933 [b]	0.27200[bc]	20.099[ba]
Kenya-4	1.3397 [c]	0.2730 [b]	20.4344 [a]	0.90667 [b]	0.18667 [b]	20.5713 [b]	1.21222 [a]	0.24333 [b]	20.0698 [b]	1.47200[ba]	0.26800 [c]	18.202[bc]
Kenya-5	1.5467 [ba]	0.3267 [a]	21.130 [a]	0.83110 [d]	0.14443 [c]	17.3981 [c]	1.21556 [a]	0.24667 [b]	20.2920[ba]	1.53733 [a]	0.33467 [a]	21.794 [a]
Korea-1	1.5500 [ba]	0.3200[a]	20.6475[a]	0.87333 [c]	0.16000 [c]	18.3228 [c]	1.23222 [a]	0.25000 [b]	20.2934[ba]	1.34933 [b]	0.27200[bc]	20.099[ba]
Korea-3	1.5300 [ba]	0.3267[a]	21.367[a]	0.86667 [c]	0.15333 [c]	17.6885 [c]	1.23556 [a]	0.25333 [b]	20.5073[ba]	1.50400 [a]	0.32667[ba]	21.722 [a]
Mult-yel	0.9403[d]	0.1483[c]	15.7737 [b]	0.80777 [d]	0.12333 [d]	15.2640 [d]	0.72889 [b]	0.11111 [c]	15.2654 [c]	0.85023 [d]	0.12843 [d]	15.218 [c]
Mult-wh	0.9270[d]	0.1363 [c]	14.7054 [b]	0.80443 [d]	0.12000 [d]	14.9023 [d]	0.72556 [b]	0.10778 [c]	14.8741 [c]	1.04137 [c]	0.16177 [d]	15.628 [c]
Pr	<0.0001	<0.0001	<0.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0019
CV	7.7314	7.327	3.881	2.038582	6.160211	5.858746	1.615740	3.434547	4.069879	6.365308	11.92655	10.39329

Means followed by the same letter within a column are not significantly different from each other at 5% level of probability

Discussion

The success of sericulture industry depends upon several factors of which the impact of the environmental factors such as biotic and abiotic factors is of vital importance. Among the abiotic factors, temperature and humidity plays a major role on growth and productivity of silkworm, as it is a poikilothermic (cold blooded) insect (Benchamin and Jolly, 1986). There is ample literature stating that good quality cocoons are produced within a temperature range of 22–27°C and significant deviations from these levels makes the cocoon quality poorer. However, polyvoltine races reared in tropical countries are known to tolerate slightly higher temperature (Hsieh, 1995), which is also true with crossbreeds, that have been evolved specially for tropical climate.

In the present study, performance of mulberry silkworm strains was tested across different environments which generally depicted a minimum and maximum temperature and humidity ranges of 19-34 °C and 25-83%, respectively. The different silkworm strains showed statistical significant differences among themselves in terms of important silkworm characters in the study locations at $p<0.05$. For example, significant variation in duration to complete different life stages was observed which include larval duration (21.67days to 32.00 days) and total life cycle duration (44.94 days to 79.67 days. Related studies conducted by Shah *et al*. (2007), studied the performance of mulberry silkworms and different seasons and different varieties and confirmed such type of variations. Moreover, significant variability among silkworm strains on egg hatchability (63.67% to 91.00%) and larval weight (1.328 grams to 3.567 grams) and effective rate of rearing (56.22% to 92.0%) were recorded which was also in conformity with Qader *et al* (1992) who observed such differences among silkworm stains through feed nutritive value studies.

In regard to cocoon parameters, this study showed single cocoon weight (0.726 grams to 1.600 grams), single shell weight (0.108 grams to 0.355 grams) and silk ratio (14.71 to 22.76%). This result is in agreement with findings of Nguku *et al* (2009) who studied performnace of different mulberry silkworm strains in neighboring country (Kenya).

In general, all differences could be justified because rearing performance in silkworms is affected by ecological, biochemical, physiological and quantitative characters, which influence growth and development, quantity and quality of silk they produce in different geographical locations (Virk *et al*, 2011; Ramesh *et al*, 2012; Anandakumar and Michael, 2012; and Reddy *et al*, 2012). Among geographically determined factors, Legay (1958) and Scriber and Slansky (1981) stated that temperatures in the range of 21–27 °C with relative humidity (RH) of 70–85% are required for silkworms effective growth and cocoon productivity. It is known that the productivity of silkworms is affected by temperature and humidity and is verified among the silkworms reared in the all locations. In addition, the nutritive value of leaves especially the moisture content may also vary to contribute to variability in performance of silkworm strains at different agro-ecological zones (Jayaramiah and Sannappa, 1998).

Conclusion

The performance of the mulberry silkworm strains across different locations can be recognized to be variable which will affect mulberry silk production and productivity in general. Therefore, rearing conditions necessitates that the silkworm strain to be reared should be both high yielder and adversity resistant.

In Summary, multivoltine strains showed significantly lower life periods as compared to bivoltine strains in all locations. They also exhibited significantly lower larval, pupal and shell weights. On the other hand, bivoltine strains have performed better than multivoltine strains in regard to commercial traits. However, the bivoltine strains have also revealed significant differences among each other. Among them, a bivoltine mulberry silkworm strain known by Kenya 1 have showed an outstanding performance compared to other strains in all locations. As a result, it is recommended for future research and development efforts on mulberry sericulture in Ethiopia.

However, a cocoon weight up to 1.60 grams that was obtained from this experiment in different locations is lower compared to the findings by Nguku *et al*. (2009) who recorded up to 2.14 grams from improved strains. Therefore, further research and improvement works are required to meet international productivity levels. Important differences in climatic conditions of different silk production areas will also require detailed investigation in future.

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Mineral profiles of agro-industrial by-products and locally available supplementary feeds and their implications for dairy cattle nutrition in Ethiopia

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Abstract

This study assessed the macro- and trace mineral profiles of major agro-industrial by-products (AIBPs) and locally available feed resources commonly used as supplementary feeds to dairy cattle in Ethiopia. A total of 58 samples belonging to five categories of supplementary feeds (compound dairy rations/concentrates, oilseed cakes, wheat bran, middling and grains, brewery by-products, and pulse grain by-products) collected from different agro-industries and local sources were included in the study. The result showed considerable differences in mineral concentrations both within and among the different categories of supplementary feeds suggesting the likelihood of complementing a mineral or minerals deficient in some of the supplementary feeds/feed ingredients by using others. The concentration of most minerals measured in compound dairy rations lied within or above the ranges recommended in dairy cattle diets. On the other hand, average mineral profile of the other supplementary feed ingredients revealed deficiencies of two or more of the following elements: K, Mg, Na, P, S, Mn, and Zn for dairy cattle. Among the locally produced supplementary feed ingredients, oats grain and the traditional liquor residue (`Areke attela`) had exceptionally high Ca content. Mineral elements' variability noted in the different feed ingredients investigated in this study indicate the nutritional significance of combining various feed supplements in dairy ration formulation in order to rectify deficiencies of different minerals. Moreover, there is a need to demonstrate the comparative advantages of compound dairy ration to the individual concentrate feed ingredients in terms of cost and supply of the nutrients required by dairy cattle in order to promote its wider utilization in major dairy shed areas.

Key words: **-**macro-minerals, trace minerals, supplementary feeds, dairy cattle nutrition, Ethiopia

Introduction

Livestock productivity in general and dairy productivity in particular is the function of nutrition, health status and genetic potential of the animal. Among these factors, nutrition plays the most important role as it represents the major cost of livestock production. A successful nutrition program requires proper balance of protein, energy, vitamins and minerals. Minerals are integral parts of nutrients required for growth and reproduction. In addition, mineral elements provide structural supports to the animal body, constituents of body fluids and serve as catalysts in both enzyme and hormone systems. In general, minerals fulfill several important functions for the maintenance of animal, growth and reproduction as well as health status. Hence, mineral inadequacies are the principal causes of reproductive failures and low production rates in dairy cattle (McDowell, 1985, 1997; Vergas and McDowell, 1997). However, in dairy cattle diets the emphasis given is skewed towards energy and protein sources with low consideration to mineral contents of the feeds. Due to this fact, mineral deficiencies and imbalances are likely to become more apparent and more critical in energy and protein rich feeds(Underwood and Suttle, 1999).In such situation cattle cannot perform to their full genetic potential unless their mineral needs are met, even if they receive 100% of their protein and energy requirements (Prasad *et al.*, 2007).

In Ethiopia, dairy cattle are mainly fed on natural pasture (grazing and/or hay), crop residues and different agro-industrial and locally available by-products as supplementary feeds. In the past, extensive studies have been carried out in the country to explore the nutritional limitations of such feeds to improved livestock production. However, most of the studies were mainly concentrated on the content and digestibility of major nutrients and not adequately addressed the aspects of mineral elements. Some studies (Kabaja and Little, 1988; Lemma and Smit, 2005 and Fekede *et al.*, 2013) have attested the low essential mineral element status of natural pastures and crop residues. On the other hand, studies on the mineral status of major agro-industrial and locally available by-products, feed resources that are widely utilized as supplement to dairy cattle, are very much limited. The work of Lemma and Smit (2005) on mineral composition of noug cake and grass pea haulm produced on Vertisols of the central highlands is one of the few documented information available in this regard. Knowledge on the mineral status of the different supplementary feed resources would help to identify the most deficient mineral elements in relation to the requirement of dairy cattle, which in turn would help to devise appropriate corrective measures. Therefore, this study was conducted to assess the important macro- and trace mineral profiles of major agro-industrial by-products and locally available supplementary feeds and their implications for dairy cattle nutrition in Ethiopia.

Materials and Methods

Collection of feed samples

Most of the feed ingredients commonly used as supplementary feeds to dairy cattle in Ethiopia constitute the by-products of different agro-industries (flour mills, oil mills and animal feed processors). Under smallholder farmers' conditions, different locally available/produced feeds such as local beverage by-products, oats grain, and different grains screenings and hulls are also used to supplement dairy cattle.

In the present study, a total of 58 samples belonging to different agro-industrial by-products and locally available feeds were collected to assess their mineral status. These feed categories more or less capture the supplements in common use by dairy cattle in the country. The categories of the different supplementary feeds, sources/locations and the number of samples collected for analysis are shown in Table 1.

Table 1. Types, number of samples and sources of the various supplementary feeds collected for mineral analysis

Category and types of supplementary feeds	No. of samples	Locations/sources
1. Compound dairy rations/concentrates		
1.1.Compound feed for lactating cows	4	Different animal feed processing plants in Addis Ababa and Bishoftu
1.2.Compound feed for pregnant cows	2	
1.3.Compound feed for heifers	2	
1.4.Compound feed for calves	2	
1.5. Compound feed for bulls	2	
2. Cereal grain mill by-products		
2.1. Wheat bran	5	Different flour and food processing factories in Addis Ababa, Bshoftu and Adama
2.2. Wheat middling	3	
2.3. Mixed grain screenings	2	Grain mills in Ejere
2.4. Oats grain	2	Holetta Research Center
3. Oil seed cakes and meals		
3.1. Noug (*Guizotia abyssinica*) seed cake	4	Different oil processing mills/factories at Modjo, Guder/Ambo, Addis Ababa and Ejere
3.2. Linseed cake	3	
3.3. Cotton seed cake	2	
3.4. Cotton seed meal	2	
4. Pulse hulls, screenings and bran		
4.1. Grass pea hull	3	Grain mills at Ejere
4.2. Field pea hull	3	
4.3. Field pea x Faba bean mixed hull	3	
4.4. Mixed pulses screenings	3	
4.5. Mixed pulses bran	3	
5. Local and industrial brewery residues		
5.1. `Areke Atela`	3	Local beverage producers in Holetta area
5.2. `Tela Atela`	3	
5.3. Industrial brewery residues	2	Meta Abo (Sebeta) & St. George (AA) breweries
Total number of samples	**58**	

Sample preparation and laboratory analysis

The samples were classified into five categories based on the nature and relative similarities of the supplementary feeds/by-products from which the samples were collected. This was purposively made for the sake of data analysis and result presentation and interpretations. The different categories included: compound ration, oil seed cakes, wheat bran, middling and grains, brewery residues (both industrial and local), and pulse hulls, screenings and bran. Upon proper drying (natural or using oven according to nature of the feed), the samples collected from the different categories of supplementary feeds were milled through a 1-mm sievesize for laboratory analysis. Analysis was made for a total of ten selected minerals including six macro-minerals (Ca, P, K, S, Na and Mg) and four trace minerals (Zn, Mn, Cu and Fe). For determination of both the macro- and trace minerals, the ground samples were dry ashed at 450°C for 4 hours in a furnace. The cooled ash was digested using 20%HNO_3 and then was filtered through a filter paper. In the filtrate, the P concentration was measured by spectrophotometer according to Murphy and Riley (1962). The concentrations of Ca, K, Mg, Na, Zn, Mn, Cu and Fe were analyzed using atomic absorption flame emission spectrometer Model AAS-6200 (Shimadzu Corp., Japan). Sulphur (S) was determined following the procedures described by Wolf (1982).Statistical Analysis System (SAS, 2002) was used for analyzing the data.

Results

Macro-minerals

The macro-mineral contents of the different AIBPs and locally produced supplementary feed resources were shown in Table 2.Significant variations ($p<0.05$) were observed in Ca, K and Mg contents among the different types of compound rations. The Ca content varied widely from 18.9 g/kg DM in bull ration to 82.6 g/kg DM in pregnant cows' ration, with a mean value of 48.3 g/kg DM. Following the pregnant cows` ration, higher Ca content was recorded in the ration of growing heifers which also had higher Na and Mg contents. Unlike Ca content, the other macro-minerals lied within relatively narrow range in the different compound rations. As opposed to Ca content, the P content was higher in bull ration than the other compound feeds. All the compound rations had low and almost similar S contents. In general, the overall average macro-mineral content of the compound dairy feeds evaluated in this study varied in the order Ca>K>Na>P>Mg>S.

Concentrations of the measured macro-minerals, except that of S and Na contents varied significantly ($p<0.05$) among the different oilseed cakes evaluated in the study. Noug cake had higher Ca and P contents ($p<0.05$) than the other oilseed cakes, while K, S and Mg contents were higher in cotton seed meal. Cotton seed cake also had better P, K and Mg contents, but relatively lower Ca and S contents. Relative to the other oilseed by-products, linseed cake had moderate concentrations of the measured macro-minerals. All the evaluated oilseed cakes had low and almost similar Na concentration and the overall mean macro-mineral contents of the different oilseed cakes varied in the order K>P>Ca>Mg>S>Na.

As shown in Table 2, the concentrations of the macro-minerals, except the S and Na contents showed significant variations ($p<0.05$) among the supplementary feeds categorized under bran, middling and grains/grain screenings. Oats grain had remarkably higher Ca content, while wheat bran, middling and mixed grains screenings were generally characterized by low Ca profile with the lowest concentration recorded in wheat middling. This shows that oats grain can be a good source of Ca for dairy cattle where it is available and used for feeding like the case of Selale area in the Ethiopian highlands. On the other hand, both wheat bran and wheat middling had comparably higher concentrations of P, K and Mg than oats grain ($p<0.05$). Mixed grains

screenings also had comparable Mg content with that of wheat bran and middling. All the supplementary feeds in this category had very low and closely ranging S and Na contents.
Concentrations of the macro-minerals except Ca did not show significant variations ($p>0.05$) in the brewery by-products. The local liquor residue (`*Areke attela*`) had very high Ca content ($p<0.05$) than both the traditional brewery residue (`*Tela attela*`) and the industrial brewery residues, which had low and comparable Ca contents (6.9 vs 8.1 g/kg DM). On the other hand, comparatively higher P and S contents were recorded in the industrial brewery residue, while `*Tela attela*` had relatively higher concentrations of K, Na and Mg. Generally, the brewery by-products evaluated in this study were characterized by low concentrations of S, Na and Mg relative to the other macro-minerals.

The result (Table 2) showed that concentrations of the macro-minerals varied significantly ($p<0.05$) among the different pulse hulls, pulse grain screenings and pulse bran evaluated in the study. Grass pea hull had significantly higher ($p<0.05$) Ca content followed by mixed pulses bran and faba bean hull, while field pea hull had lower concentration of Ca followed by mixed pulses grain screenings. The concentration of P was significantly higher ($p<0.05$) in mixed pulses grain screenings followed by mixed pulses bran, while the lowest P concentration was recorded in faba bean hull. On the other hand, both grass pea hull and field pea hull had closely comparable P contents. Mixed pulses grain screenings also had significantly higher ($p<0.05$) K content followed by grass pea hull and faba bean hull, while mixed pulses bran had lowest K content. All the pulse by-products generally had lower concentrations of S, Na and Mg. However, mixed pulses grain screenings had comparatively higher S content, while grass pea hull had higher concentrations of Na and Mg followed by faba bean hull.

This study also revealed considerable differences among the different categories of supplementary feeds in terms of average concentrations of the different macro-minerals. Compound rations had higher concentrations of Ca and Nathan the other supplementary feed resources. Oilseed cakes were found to be rich in most macro-minerals (P, K, S and Mg), but had lower Ca content as compared to the other supplementary feeds. Pulse hulls, pulse grain screenings and pulse bran had lower concentrations of P, S and Mg than the other supplementary feeds. Cereal (wheat) bran, middling and grain/grain screenings had lower Na content as compared to the other supplementary feed resources. Lower K and Mg contents were also observed in the brewery by-products than the other supplementary feeds evaluated in this study. In general, compound rations had higher concentration of Ca followed by brewery residues and wheat bran, middling and grains, while oilseed cakes were rich in P and K followed by compound rations.

Table 2. Macro-mineral profiles of different AIBPs and locally available supplementary feeds

Type and description of the supplementary feed	(g/kg DM)					
	Ca	P	K	S	Na	Mg
I. Compound ration						
Lactating cows ration	42.4^{ab}	6.5	11.3^{ab}	0.6	9.3	3.3^{ab}
Pregnant cows ration	82.6^{a}	6.9	12.9^{a}	0.7	8.4	4.0^{a}
Growing heifers ration	66.5^{ab}	6.5	11.1^{b}	0.7	11.0	4.1^{a}
Calf ration	30.9^{ab}	7.7	11.9^{ab}	0.7	8.4	3.8^{a}
Bull ration	18.9^{b}	8.2	10.5^{b}	0.6	9.1	2.4^{b}
Mean±SE	***48.3±11.6***	***7.2±0.3***	***11.5±0.4***	***0.7±0.0***	***9.2±0.5***	***3.5±0.3***
II. Oilseed cakes						
Noug cake	8.0^{a}	12.2^{a}	13.1^{ab}	1.4	0.4	4.1^{b}
Linseed cake	6.9^{ab}	7.2^{b}	11.6^{b}	1.5	0.5	4.0^{b}
Cotton seed cake	4.6^{b}	9.8^{ab}	15.2^{a}	1.2	0.5	4.5^{a}
Cotton seed meal	5.3^{ab}	11.6^{a}	16.5^{a}	1.9	0.5	4.5^{a}
Mean±SE	***6.2±0.8***	***10.2±1.1***	***14.1±1.1***	***1.5±0.1***	***0.5±0.0***	***4.3±0.1***
III. Wheat bran, middling and grains						
Wheat bran	2.2^{b}	11.4^{a}	13.2^{a}	0.6	0.5	2.8^{a}
Wheat middling	0.5^{b}	9.3^{a}	12.2^{a}	0.5	0.4	2.4^{a}
Oats grain	56.5^{a}	4.2^{b}	5.3^{b}	0.7	0.2	1.5^{b}
Mixed grains screenings	2.5^{b}	2.5^{b}	3.8^{b}	0.4	0.3	2.5^{a}
Mean±SE	***15.4±13.7***	***6.9±2.1***	***8.6±2.4***	***0.6±0.1***	***0.4±0.1***	***2.3±0.3***
IV. Brewery residues (industrial and locally produced)						
Brewery residue	8.1^{b}	6.0	0.7	1.1	0.3	1.9
Areke Attela*	44.2^{a}	3.8	4.1	0.7	0.4	1.5
Tela Attela[@]	6.9^{b}	4.5	6.5	0.9	0.7	2.0
Mean±SE	***19.7±12.2***	***4.8±0.6***	***3.8±1.7***	***0.9±0.1***	***0.5±0.1***	***1.8±0.2***
V. Pulse hulls, screenings and bran						
Grass pea hull	11.5^{a}	1.8^{c}	10.5^{b}	0.3^{c}	0.9^{a}	2.3^{a}
Field pea hull	4.1^{e}	1.7^{c}	7.8^{d}	0.4^{b}	0.6^{c}	1.3^{e}
Faba bean hull	7.0^{c}	1.2^{d}	8.3^{c}	0.4^{b}	0.7^{b}	1.9^{b}
Mixed pulses screenings	5.4^{d}	4.7^{a}	11.4^{a}	0.8^{a}	0.5^{d}	1.7^{c}
Mixed pulses bran	7.8^{b}	3.2^{b}	4.7^{e}	0.4^{b}	0.6^{c}	1.6^{d}
Mean±SE	***7.2±1.3***	***2.5±0.6***	***8.5±1.2***	***0.5±0.1***	***0.7±0.1***	***1.8±0.2***

[a-e]Mean values with different superscripts for each categories of supplementary feeds in a column differ significantly ($p<0.05$)

*- a traditional home-made liquor residue; [@]- a traditional home-made brewery residue

Trace minerals

Table 3 shows the trace mineral contents of different AIBPs and locally available supplementary feed resources. Among the compound rations, bull ration had higher Zn content followed by growing heifers ration and lactating cows` ration, while calf ration and pregnant cows ration had comparatively lower Zn concentration. The concentration of Mn was significantly higher ($p<0.05$) in calf ration followed by bull ration and lactating cows ration, and was lower in pregnant cows ration. The concentration of Cu in compound rations varied in the order lactating cows ration>pregnant cows ration>bull ration>growing heifers ration>calf ration. The concentration of Fe was higher in pregnant cows ration followed by growing heifers ration and lactating cows` ration, while bull ration had relatively lower Fe content.

Concentrations of all the measured trace minerals showed significant variations ($p<0.05$) among the different oilseed cakes evaluated in the study. Linseed cake had significantly higher ($p<0.05$) Zn content followed by noug cake and cotton seed meal, while cotton seed cake had lower Zn concentration. On the other hand, noug cake had higher Mn concentration followed by linseed cake, while cotton seed cake and cotton seed meal had comparably lower Mn contents. The Cu content of the oilseed cakes varied in the order linseed cake>noug cake>cotton seed cake>cotton seed meal. Noug cake had considerably higher concentration of Fe followed by linseed cake, while cotton seed cake and cotton seed meal had lower Fe contents.

As shown in Table 3, concentrations of trace minerals also showed significant variations ($p<0.05$) among the supplementary feeds categorized under bran, middling and grains/grain screenings. Wheat bran had higher Zn content followed by wheat middling, while oats grain and mixed grains screenings had lower and very closer Zn contents. The concentration of Mn in this category of supplements also varied widely from as low as 27.1ppm in mixed grains screenings to as high as 113.4ppm in wheat middling. The Cu content was higher in wheat bran followed by mixed grains screenings and wheat middling, while oats grain had lower concentration of Cu. On the other hand, Fe content of these feed resources varied in the order mixed grains screenings>oats grain>wheat middling>wheat bran.

Among the brewery by-products evaluated in this study, the industrial brewery residue had higher Zn content followed by `*Areke attela*`, while `*Tela attela*` had relatively lower Zn content. On the other hand, the concentrations of both Mn and Fe were higher in `Tela attela` followed by `*Areke attela*`, and were lower in brewery residue. The concentration of Cu in these by-products varied in the order `*Areke attela*`>`*Tela attela*`>brewery residue.

The result (Table 3) showed significant variability in concentrations of trace minerals in the different pulse hulls, pulse grain screenings and pulse bran evaluated in the study ($p<0.05$). The Zn content varied from as low as 9.1ppm in faba bean hull to as high as 42.9ppm in mixed pulses screenings with a mean of 28.9ppm. The concentration of Mn varied in the order mixed pulses bran>grass pea hull>mixed pulses screenings>field pea hull>faba bean hull. Mixed pulses screenings had higher concentration of Cu followed by mixed pulses bran and faba bean hull, while grass pea hull and field pea hull had comparatively lower Cu contents. The concentration of Fe showed wide variability among the different pulse grain by-products and varied from as low as 94.8ppm in faba bean hull to as high as 454.2ppm in mixed pulses bran. It was generally noted that faba bean hull had lower concentrations of most of the measured trace minerals, while mixed pulses screenings and bran had comparatively higher levels of trace minerals.

As depicted in Table 3, average concentrations of trace minerals also showed considerable differences among the different categories of supplementary feeds evaluated in the study. The mean concentration of Zn varied in the order compound rations>brewery residues>wheat bran, middling and grains>oilseed cakes>pulse hulls, screenings and bran. Similarly, the mean Mn content was higher in compound rations followed by wheat bran, middling and grains and oilseed cakes, while brewery residues and pulse grain by-products had relatively lower concentration of Mn. Oilseed cakes had higher Cu content followed by brewery residues and compound rations, while wheat bran, middling and grains and pulse grain by-products had comparatively lower concentration of Cu. The average Fe concentration in the different supplementary feeds varied in the order oilseed cakes>compound rations>brewery residues>pulse hulls, screenings and bran>wheat bran, middling and grains. In general, compound rations were found to be rich in Zn and Mn, while oilseed cakes had higher concentrations of Cu and Fe among the different supplementary feeds evaluated in this study.

Table 3. Trace mineral profiles of different AIBPs and locally available supplementary feeds

Type and description of the supplementary feed	ppm			
	Zn	Mn	Cu	Fe
I. Compound ration				
Lactating cows ration	81.9	157.7^{ab}	47.9	306.9
Pregnant cows ration	69.1	97.4^{b}	45.6	488.2
Growing heifers ration	92.2	143.0^{b}	32.1	376.3
Calf ration	72.9	222.1^{a}	21.4	297.0
Bull ration	95.1	165.4^{ab}	34.7	218.9
Mean±SE	***82.2±5.1***	***157.1±20.1***	***36.3±4.8***	***337.5±45.2***
II. Oilseed cakes				
Noug cake	46.6^{ab}	113.2^{a}	52.9^{b}	962.4^{a}
Linseed cake	57.5^{a}	82.1^{a}	92.5^{a}	840.9^{a}
Cotton seed cake	33.0^{b}	20.4^{b}	42.5^{b}	134.7^{b}
Cotton seed meal	41.4^{ab}	21.1^{b}	40.6^{b}	80.4^{b}
Mean±SE	***44.6±5.1***	***59.2±23.1***	***57.1±12.1***	***504.6±230.8***
III. Wheat bran, middling and grains				
Wheat bran	90.8^{a}	105.9^{a}	39.1^{a}	69.0^{c}
Wheat middling	69.1^{b}	113.4^{a}	23.8^{ab}	132.4^{b}
Oats grain	33.9^{c}	45.6^{b}	5.0^{b}	145.3^{b}
Mixed grains screenings	34.5^{c}	27.1^{c}	33.0^{ab}	319.7^{a}
Mean±SE	***57.1±13.9***	***73.0±21.5***	***25.2±7.4***	***166.6±53.7***
IV. Brewery residues (industrial and locally produced)				
Brewery residue	77.1	29.3^{b}	31.2	264.2
Areke Attela*	50.9	32.0^{b}	55.2	274.7
Tela Attela$^{@}$	43.8	55.6^{a}	49.3	408.1
Mean±SE	***57.3±10.1***	***39.0±8.4***	***45.2±7.2***	***315.7±46.3***
V. Pulse hulls, screenings and bran				
Grass pea hull	20.2^{d}	43.9^{b}	8.2^{e}	258.2^{c}
Field pea hull	31.4^{c}	26.7^{d}	12.1^{d}	145.8^{d}
Faba bean hull	9.1^{e}	22.2^{e}	26.5^{c}	94.8^{e}
Mixed pulses screenings	42.9^{a}	39.5^{c}	36.8^{a}	417.4^{b}
Mixed pulses bran	41.0^{b}	60.5^{a}	34.5^{b}	454.2^{a}
Mean±SE	***28.9±6.4***	***38.6±6.8***	***23.6±5.8***	***274.1±71.4***

$^{a-e}$Mean values with different superscripts for each categories of supplementary feeds in a column differ significantly ($p<0.05$)

*- a traditional home-made liquor residue; $^{@}$- a traditional home-made brewery residue

Discussion

The recommended concentrations of various minerals in diets for satisfactory nutrition of dairy cattle are documented in different editions of National Research Council (NRC, 1989, 2001). Table 4 shows the ranges and average concentrations of important macro and trace minerals in the different categories of supplementary feed resources evaluated in this study in comparison to the NRC recommendations for dairy cattle. It can be noted that compound rations had higher concentrations of Ca, Na, Mg, Mn, Cu and Fe than the levels recommended in dairy cattle diets. On the other hand, the concentrations of P, K and Zn in the compound rations did closely match with the NRC recommendations, while the S content lied below the recommended levels for satisfactory nutrition of dairy cattle. However, except the Ca content average concentrations of the other minerals measured in compound rations in the present study were lower than the maximum tolerable concentrations in the diets of dairy cattle (NRC, 1989, 2001). The observed high level of Ca in the compound rations may indicate the high emphasis given by feed processors to include more sources of Ca while formulating the compound feeds. Nevertheless, feed processing plants who have been engaged in the preparation of compound rations should have information on the recommended levels of different minerals for optimum nutrition of dairy cattle and opt to fix proportions of the different feed ingredients accordingly. This not only helps to avoid using a variety of costly ingredients with no apparent justification, but also enables to prevent diseases and reproductive disorders which may occur as a result of mineral imbalances in the diet.

Relative to the Ca content, average concentration of P in the compound rations evaluated in this study was low resulting in wider Ca:P ratio (on average 6.7:1). Calcium and Phosphorous are closely related and laid down in bone in a ratio of 2.2 parts Ca to 1 part P. This implies that a deficiency or an overabundance of either mineral could interfere with the proper utilization of the other, as an imbalance of either mineral can cause them to bind with each other and become unavailable to the animal (Harris *et al*., 2003). Although, it is generally recommended that diets of livestock should have Ca:P ratio of about 1:1 to 2:1 (Underwood, 1981), livestock can tolerate dietary Ca:P ratios of more than 10:1 without any serious effect provided the P intake is adequate (Ternouth, 1990). Wider Ca:P ratios, however, are detrimental in feeds apparently deficient in P (Wan Zahari *et al.,* 1990). As the P content of the compound rations evaluated in the current study fall within the recommended range for dairy cattle, the observed wider Ca:P ratio may not have undesirable consequences to dairy animals fed on these feeds. In general, the compound rations evaluated in this study could fulfill the requirement of dairy cattle for most of the important minerals as per the NRC recommendations except S. This suggests that feeding dairy cattle using these feeds is essential for addressing the requirement of dairy animals with regard to mineral nutrition. However, studies have revealed that compound rations were rarely used by smallholder peri-urban dairy farmers in selected milk shed areas (Ejere, Sululta and Girar-Jarso)in the central highlands of Ethiopia (Fekede, 2013). According to the sample dairy farmers in the study areas, unlike the other feed ingredients such as wheat bran, compound rations were not readily available in the local market. Moreover, the farmers did not have adequate knowledge on comparative advantages of compound rations in terms of both cost and feeding value. This was further witnessed by the compound feed processors who indicated that they usually supply their product to large scale commercial/urban dairy farms based on pre-requested demand. This suggests the need to promote the use of compound rations especially by improved dairy producers including the smallholder systems while demonstrating their comparative advantage to the individual feed ingredients in terms of cost and supply of nutrients required by dairy cattle.

The average concentrations of Ca, P, K and Mn in the oilseed cakes evaluated in this study fall closer to and/or within the ranges recommended for satisfactory nutrition of dairy cattle (NRC, 1989, 2001). On the other hand, Mg, Cu and Fe contents of the oilseed cakes lie above the recommended ranges, while S, Na and Zn fall below the ranges recommended for satisfactory nutrition of dairy cattle indicating the need to consider supplementations with other sources of these minerals when oilseed cakes are used as supplementary feeds to dairy cattle. However, the average concentrations of all the minerals in the oilseed cakes were lower than the maximum tolerable levels of the respective minerals in the diets of dairy cattle.

Wheat bran, middling and mixed grains screenings had very marginal Ca contents relative to NRC recommendations in dairy cattle diet, while the concentration of Ca in oats grain was higher than the maximum tolerable concentration in the diets of dairy cattle. On the other hand, wheat bran and middling had higher contents of P, K and Mg which can meet the requirements of dairy cattle as compared to oats grain. In view of this, mixing ground oats grain with wheat bran while feeding dairy cattle where applicable could be a suitable strategy to meet the requirement of dairy cattle for Ca, P, K and Mg. This may also help to correct the Ca:P ratio to the desirable range. The average concentrations of S and Na in wheat bran, middling, oats grain and mixed grains screenings evaluated in this study were lower than the recommended ranges in dairy cattle diets (NRC, 1989, 2001) suggesting the need for supplementations with sources of these minerals. Relative to the NRC recommendations, wheat bran and middling could meet the requirement of dairy cattle for all the trace minerals (Zn, Mn, Cu and Fe) measured in this study, while oats grain and mixed grains screenings had lower Zn and Mn contents than the NRC recommendations. Moreover, oats grain had much lower Cu content than the range recommended for satisfactory nutrition of dairy cattle.

Among the brewery by-products evaluated in this study, the local liquor residue (`Areke attela`) had much higher Ca content than the maximum tolerable concentration, while the P content of all the brewery by-products was fairly within the range recommended in dairy cattle diets (NRC, 1989, 2001). On the other hand, concentrations of the other macro-minerals (K, S, Na and Mg) in the brewery by-products lied below the recommended levels in the diets of dairy cattle. The Cu and Fe contents of the brewery by-products lied above the NRC recommendations in dairy cattle diets, but lower than the maximum tolerable concentrations (NRC, 1989, 2001).

The concentration of Zn in the industrial brewery residue and the Mn content in the traditional home-made brewery residue (`*Tela attela*`) lied within the recommended levels of the minerals in dairy cattle diets. Relative to the NRC recommendations in dairy cattle diets (NRC, 1989, 2001), `*Areke attela*` and `*Tela attela*` were deficient in Zn, and the industrial brewery residue and `*Areke attela*` were deficient in Mn contents.

The average concentrations of P, K, S, Na and Mn in pulse grain by-products evaluated in this study lied below, while the average Ca content lied within the range recommended for satisfactory nutrition of dairy cattle (NRC, 1989, 2001). Grass pea hull, faba bean hull and mixed pulses bran had relatively high Ca content which can meet the requirement of dairy cattle as per the NRC recommendation. Moreover, the concentration of K recorded in grass pea hull and mixed pulses screenings lied within the ranges recommended in dairy cattle diets. The Mg content recorded in grass pea hull and faba bean hull could also meet the requirement of dairy cattle. Among the trace minerals measured in pulse grain by-products, Cu and Fe could meet the dietary requirement of dairy cattle, while the mean Zn and Mn levels were relatively lower than the NRC recommendations. However, the concentration of Mn recorded in mixed pulses bran could meet the requirement of dairy cattle.

Table 4. Comparison of mineral contents of the different supplementary feed resources with NRC recommendations for satisfactory nutrition of dairy cattle

Mineral	NRC recommendation	Range and average concentration of minerals in the different supplementary feeds evaluated in this study				
		Compound rations	Oilseed cakes	Wheat bran, middling and grains	Brewery by-products	Pulse grain by-products
g/kg DM						
Ca	7-11 (20)	18.9-82.6, 48.3*	4.6-8, 6.2*	0.5-56.5, 15.4*	6.9-44.2, 19.7*	4.1-11.7, 7.2*
P	4-9 (10)	6.5-8.2, 7.2*	7.2-12.2, 10.2*	2.5-11.4, 6.9*	3.8-6, 4.8*	1.2-4.7, 2.5*
K	9-14 (30)	10.5-12.9, 11.5*	11.6-16.5, 14.1*	3.8-13.2, 8.6*	0.7-6.5, 3.8*	4.7-11.4, 8.5*
S	2.0-2.5	0.6-0.7, 0.7*	1.2-1.9, 1.5*	0.4-0.7, 0.6*	0.7-1.1, 0.9*	0.3-0.8, 0.5*
Na	1.8-4.5	8.4-11, 9.2*	0.4-0.5, 0.5*	0.2-0.5, 0.4*	0.3-0.7, 0.5*	0.5-0.9, 0.7*
Mg	2.0-2.5 (5)	2.4-4.1, 3.5*	4-4.5, 4.3*	1.5-2.8, 2.3*	1.5-2, 1.8*	1.3-2.3, 1.8*
mg/kg DM						
Zn	70-80 (500)	69.1-95.1, 82.2*	33-57.5, 44.6*	33.9-90.8, 57.1*	43.8-77.1, 57.3*	9.1-42.9, 28.9*
Mn	50-60 (1000)	97.4-222.1, 157.1*	20.4-113.2, 59.2*	27.1-113.4, 73*	29.3-55.6, 39*	22.2-60.5, 38.6*
Cu	12-30 (100)	21.4-47.9, 36.3*	40.6-92.5, 57.1*	5-39.1, 25.2*	31.2-55.2, 45.2*	8.2-36.8, 23.6*
Fe	50-100 (1000)	218.9-488.2, 337.5*	80.4-962.4, 504.6*	69-319.7, 166.6*	264.2-408.1, 315.7*	94.8-454.2, 274.1*

Figures in the brackets indicate the maximum tolerable concentrations of minerals in dairy cattle diet (NRC, 1989, 2001)
*Indicate mean values

Conclusions and Implications

Mineral contents showed considerable differences both within and among the different categories of supplementary feeds evaluated in this study. This difference is vital as it helps to single out the potential feed ingredients that are likely be used to address mineral deficiencies or to exploit complimentary feed resources for a given situation. Though limited in availability and utilization, the compound rations evaluated in the study could fulfill the requirement of dairy cattle for most of the important minerals. Hence, promotion of these feeds in major dairy shed areas where productive cows are raised could be vital to address mineral deficiencies. Average mineral profiles of the other supplementary feed ingredients revealed deficiencies of S, Na and Zn in oilseed cakes; S and Na in wheat bran, middling and cereal grain/grain by-products; K, S, Na and Mg in brewery by-products, and P, K, S, Na, Mg, Zn and Mn in pulse grain by-products relative to the levels recommended in dairy cattle diets. Among the locally available supplementary feeds, oats grain and the traditional liquor residue *(`Areke attela`)* had exceptionally high Ca content and help to rectify Ca deficiency when used in mixture with low Ca deficient feed ingredients such as wheat bran and middling. In general, the different supplementary feeds evaluated in this study had excess of some minerals, optimum quantity of some minerals and deficient in some other minerals relative to the levels recommended in dairy cattle diets. Therefore, feeding dairy cattle using a compound ration composed of the different feed ingredients could help to meet mineral requirements of the dairy animal via exploitation of complementarities of mineral concentrations in the different ingredients.

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Consumption of indigenous chicken in Metekel Zone of BeniShangul Gumuz Region, Ethiopia

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Abstract

A survey was conducted to understand poultry (meat and egg) consumption in Metekel zone of BeniShangul Gumuz Region of Ethiopia. A total of 119 respondents were interviewed from four districts. About 62 per cent of the respondents were from the rural areas. Sources of chicken for the respondents are market (34.4%), own production (27.7%), neighbor (2.5%) and combination of sources (35.3%). About 53 and 66 per cent of respondents preferred eggs and meat, respectively, based on breeds. About 55 per cent of respondents prefer meat from indigenous chicken. Only about 13 per cent of the respondents consume chicken meat at a frequency of more than once in a month and this is less than the frequency of consumption of beef and goat meat. Average annual chicken consumption per household is 8.5 (SD=3.48) chicken while average egg consumption per month was slightly higher than 10 eggs. Age, plumage colour and size of chicken were main factors in the choice of live chicken during purchasing while size and egg shell colour are important criteria for choice of eggs. Multiple response queries on preference for parts of chicken carcass indicated that 93.3% have preference for drumstick and 54.6 per cent for wing and gizzard. Consumption of neck, head, blood, digits and intestine is reported by 86.5, 58, 22, less than 2, and 14 per cent of the respondents, respectively. About 85 and 63 per cent of respondents are willing to continue consumption of chicken meat and egg, respectively, even if the price increases. The information in this study, along with information on marketing aspect of poultry in the area, can serve as input in designing poultry development and improvement in the area.

Keywords: - meat, egg, indigenous chicken, consumption, preference, plumage color
Short Running title: Consumption of Indigenous Chicken

Introduction

Backyard poultry production is an important activity in most parts of Ethiopia (Worku et al., 2012) particularly where crop-livestock mixed agriculture is common. About 96.5 per cent of chicken in the country are indigenous. Under improved management condition the productivity of the indigenous chicken is low as compared to exotic chicken (Halima, 2007). Improvement of the indigenous chicken and their management is important to raise production from the indigenous chicken adapted to the low input system of management. Information on backyard chicken production system is required to design appropriate interventions to raise productivity and improve the livelihood of producers. The backyard type of chicken production is dominantly of subsistence type. Transition to market oriented chicken production can benefit from adequate knowledge on aspects of consumption of chicken and their products. In addition, the local chicken sector constitutes a significant contribution to human livelihood by being affordable sources of animal protein and contributes significantly to food security of poor households (Reta, 2009). Therefore, information on the consumption aspect of the backyard type of production from both the production and the market side need to be obtained so that along with other biological, environmental and management related information, it will be used to design ways of improving the efficiency of the system and the producers' benefit.

Metekel zone of BeniShangul Gumuz National Regional State in Ethiopia is among the areas where the majority of chicken kept under backyard system of production are indigenous (Solomon et al., 2013). Consumption and sale of these chickens make sizeable contribution to the livelihood of the people in some areas of the zone. In Ethiopia it is reported that the number of children which are under weight is more than 30% while stunted children account for about 50% (FAO, 2013). Due to low development of agriculture the situation in BeniShangul Gumuz is likely to be worse than the national figure. Interventions to raise production and productivity of chicken in this area can contribute to improvement of the situation in relation to child malnutrition and livelihood. Therefore, this study was part of a wider study to understand the genetic resource, chicken management and other related aspects and deals with the consumption aspect of indigenous chicken. The objective was to understand the level and pattern of consumption of indigenous chicken in Metekel Zone of BeniShangul Gumuz National Regional state.

Materials and Methods

Description of the study area:

The study was conducted in Guba, Dibate, Wembera districts and Gilgel Beles town (Mandura istrict) of Metekel zone of BeniShangul Gumuz National Regional State. About 80% of the zone is characterized by having sub-humid and humid tropical climate (Solomon et al., 2013). The choice of the districts was purposive with consideration to accessibility and representation of the different agro-ecologies in the zone. Accordingly Guba district represents lowland setting, while Dibate and Wembera represent mid-altitude and highland areas of the zone, respectively. Gilgel Beles is the zonal capital and due to the presence of large urban population in the town it was assumed that major poultry consumption would take place in this town. Two rural and one urban villages were sampled from each district purposively by considering accessibility and inclusion of diverse communities (indigenous and settlers). In Gilgel Beles town two localities were selected randomly. Interviewees were selected purposively considering accessibility.

Data collection

Data were collected using a questionnaire. A total of 119 consumers (Table 1) were interviewed using the questionnaire. In the questionnaire, *inter alia*, information on description of the respondent, characterizing the religious and ethnic background, income level, family size, pattern and level of poultry and poultry products consumption have been included. The questionnaires were composed of both close and open ended questions and were improved after field pre-test. Enumerators were recruited among development agents in each locality and were provided with theoretical and practical training on managing the questionnaire.

Data analysis and interpretation

Responses for all close ended questions were coded and entered into Statistical Package for Social Sciences (SPSS, version 17) software, while open ended questions were listed to determine the types of category of responses, then coded and entered into the same software. Analysis of data was also done using the descriptive statistics procedure of SPSS along with chi-square analysis.

Results and Discussion

A total of 119 consumers were interviewed with disproportionately larger samples taken from the three districts (to have proportional representation for the area and population) than the one town included in the study. Both urban (non-agricultural) and rural samples were taken (Table 1). The distribution of consumers with respect to their location showed that 61.3, 37.8 and 0.8 per cent live in rural, urban and in both (having homes in rural and urban) areas respectively. In the study area it is expected that the income level of urban dwellers to be better than rural dwellers and this may have a bearing on level, type and pattern of food consumption.

Description of the respondents

Followers of Orthodox Christian, Muslim, other Christian denominations and traditional beliefs constituted about 65.5, 18.5, 14.3 and 1.7 per cent of the respondents (Table 2), respectively. The consumption, demand and supply situation and price pattern of poultry in Ethiopia is highly related to fasting and feasting periods of the various religious beliefs (Aklilu, 2007; Fisseha and Tadelle, 2010). Therefore understanding the distributions along the religious beliefs of the consumers is important in interpretation of the results in relation to periodic patterns of poultry consumption.

Table 1. Distribution of respondents participating in the survey in relation to location

Site	Consumer location			Total
	Rural	Urban	Both	
Guba district	24	12	0	36
Gilgel Beles town	0	12	0	12
Wembera district	25	10	1	36
Dibate district	24	11	0	35
Total	73	45	1	119
Per cent	61.3	37.8	0.8	100

Table 2. Distribution of respondents in relation to religious affiliation

Site	Religion				Total	Pearson Chi-square Test
	Orthodox Christian	Muslim	Other Christians	Traditional beliefs		
Guba district	15	18	3	0	36	57.683***
Gilgel Beles town	11	1	0	0	12	
Wembera district	34	0	2	0	36	
Dibate district	18	3	12	2	35	
Total	78	22	17	2	119	
Per cent	65.5	18.5	14.3	1.7	100	

*** Significant at P<0.001

There is significant difference among districts in terms of religion of respondents where Guba has a balanced Muslim and Christian respondents while Gilgel Beles and Wembera are highly skewed towards followers of Orthodox Christianity. In Dibate Christians are highly dominant with relatively balanced proportion between Orthodox and the other Christian denominations. In areas where the Orthodox Christians are the majority, because of the annual vegan fasting observed by the followers during various periods (which totals more than half of the calendar year) it is highly likely that decrease in demand to occur (Fisseha and Tadelle, 2010). During other periods the demand increases, and production and marketing aspects need to consider this periodical change to design or adjust production and marketing accordingly. As an option planning for increased demand during festivals and improving storage of eggs have been suggested (Aklilu, 2007) and are worth considering in the areas covered by this study.

With respect to ethnic distribution about 33.9, 24.6, 22, 10.2, 6.7 and 2.5 per cent of the respondents belong to Gumuz, Shinasha, Amhara, Oromo, Agew and Tigre ethnic group (Table 3). Gumuz and Shinasha are indigenous people in the area and it is befitting that the sample size from this ethnic groups was high. The ethnic distribution of the sampled respondents is found to be different from the sample used in poultry production system study in the same zone by Solomon et al. (2013) where sample from the Amhara ethnic group was the highest.

Table 3. Ethnic distribution of the respondents across sites

Site	Ethnic group of the respondent						Total	Chi-square test
	Gumuz	Shinasha	Agew	Amhara	Tigre	Oromo		
Guba district	18	3	2	8	2	3	36	73.725***
Gilgel Beles town	0	2	4	6	0	0	12	
Wembera district	1	21	1	6	1	6	36	
Dibate district	21	3	1	6	0	3	34	
Total	40	29	8	26	3	12	118	
Per cent	33.9	24.6	6.7	22	2.5	10.2	100	

*** Significant at P<0.001

Due to suspicion that the information they provide might be used for taxation purpose (development agents involved as enumerators, at times are involved in facilitating collection of tax), reliable information on income was difficult to obtain even if attempt was made to persuade respondents by explaining about the objective of the study. Guba was the only district where information on income was obtained on about 61 per cent of the sample. In Guba district about 55 per cent of the households have a monthly income of birr 1200 (≈65 USD) or less, while about 36 and 9 per cent have incomes of 1200 to 3000 and higher, respectively.

The average household size in the study area was found to be about 7 with a range of 3 to 9 across sites. The largest average household size was observed in Guba while the lowest was in Gilgel Beles town. The number of observation for Gilgel Beles town was very small and the average household size need to be taken with caution. Almost all households have 1 to more than 4 children less than 14 years of age. About 50% of the households have 1 to more than 4 children of age 14 or above. Poultry (meat and egg) is among the most important sources contributing to balanced nutrition to children and the consumption level and pattern in this study need also to be looked at in that light. The average household size is more than reported national average household size of 4.6 persons (CSA, 2012) and 4.06 persons in the same area (Solomon et al., 2013) but comparable to 6.0 and 6.9 persons for Jarso and Dale districts (Eskinder,2012) and 6.2 persons for Bure district in Ethiopia (Fisseha et al., 2010).

The number of male headed households accounted for about 91 per cent of the respondent households. Obviously this is the reflection of the rarity of female headed households in all of the areas unless the household is headed by a widow or divorcée. The proportion of female headed households in the current study is higher than proportions obtained in other parts of the country (Awol, 2010). The low proportion of the female headed households doesn't reflect the differential involvement of gender in chicken consumption or ownership. As elsewhere in the country (e.g. Aklilu, 2007), in almost all households, it is mostly women who are responsible for poultry production, consumption and sell.

About 17% of respondents were illiterate while the others have educational background ranging from first grade to higher than grade twelve. Information on disaggregated consumption of indigenous chicken across education level is not generated from this study. Occupation wise the respondents are mainly engaged in framing (53.5%), while traders, school children and respondents with other employments (civil servants, private employees etc.) account for 53.5, 20.8, 4 and 21.8 per cent.

The source of chicken for the respondent households varies and about 34, 28, 3 and 35 per cent of the respondents obtain chicken from market, own production or market, from their neighbors or from a combination of sources, respectively. Similarly about 23 per cent of use for home consumption has been reported in other parts of the country (Mulugeta and Tebekew, 2013).

About 53 and 66 per cent of the respondents have preference for eggs and meat, respectively, based on breeds (Table 4) but about 22 per cent do not get their choice mainly because of unavailability. There is no one single dominant reason for the choice of egg or meat based on the breed of chicken and reasons range from taste, attractiveness, availability, ability to stay longer to being better nutritious than the other. About 62 per cent of the respondents indicated that they prefer indigenous chicken while 11 per cent preferred the exotic ones. The remaining 27% of the respondents have no specific preference. Similar preference based on breed has been reported by Aklilu (2007) by consumers in Tigray region.

Table 4. Presence of preference for egg and meat based on chicken breed

Site	Presence of preference					
	Egg			Meat		
	Yes	No	Total	Yes	No	Total
Guba district	11	25	36	18	15	33
GilgelBeles town	9	3	12	11	1	12
Wembera district	15	21	36	17	18	35
Dibate district	28	7	35	30	5	35
Total	63	56	119	76	39	115
Per cent	52.9	47.1	100	66.1	33.9	100

The source of consumed egg is mainly from own production and market (Table 5). Similarly, Fisseha and Tadelle (2010) have reported that in Bure district home consumption of chicken to be the major use. Very small quantity is sourced from neighbors. Among respondent households own production has accounted for 47.5 per cent while 34.7 per cent depend on market as source of egg they may consume. In terms of preference for egg about 33 per cent prefer egg from indigenous chicken while about 20 per cent prefer egg from exotic chicken. Over 47 per cent of the respondents prefer both and do not make discrimination between eggs from indigenous and exotic chicken (Table 6).

Table 5. Sources of egg for the respondent households

Site	Source of egg				Total
	Market	Own production and/or market	Neighbor	Combination of sources	
Guba district	8	16	1	10	35
Gilgel Beles town	10	0	0	2	12
Wembera district	12	23	0	1	36
Dibate district	11	17	0	7	35
Total	41	56	1	20	118
Per cent	34.7	47.5	0.8	16.9	100

Table 6. Respondents preference for egg and chicken meat from exotic or indigenous chicken

Site	Preferred breed of chicken							
	Egg				Meat			
	Local	Exotic	Both	Total	Local	Exotic	Both	Total
Guba District	10	1	25	36	16	2	15	33
Gilgelbeles town	3	6	3	12	10	1	1	12
Wembera district	12	3	21	36	16	1	18	35
Dibate district	14	13	7	34	21	9	5	35
Total	39	23	56	118	63	13	39	115
Per cent	33.1	19.5	47.4	100	54.8	11.3	33.9	100

Respondents' chicken meat preference shows that about 55 per cent prefer meat from local chicken while about 11 per cent have preference for meat from exotic chicken. About 34 per cent have no special preference and use meat from both local and exotic chicken (Table 6).

Seventy-eight per cent of respondents get what they prefer while 22 per cent do not. Unavailability is the most common reason for not getting what respondents prefer followed by high price of the product.

Table 7. Distribution of respondents with regard to place of consumption of chicken meat

Site	Place of consumption							
	Meat				Egg			
	Home	Home and cultural ceremonies	Home and other places	Total	Home	Home and cultural ceremonies	Home and other places	Total
Guba district	25	5	6	36	24	3	3	30
Gilgel Beles	9	2	1	12	11	1	0	12
Wembera district	25	6	5	36	22	4	8	34
Dibate district	9	16	10	35	16	10	9	35
Total	68	29	22	119	73	18	20	111
Per cent	57.1	24.4	18.5	100	65.8	16.2	18.0	100

About 57 per cent of the respondents consume chicken meat only in their homes while about 43 percent consume either at home or during cultural ceremonies and at home and other places (hotels) (Table 7). With respect to place of consumption of eggs the majority (about 66 per cent) consume only at home while the remaining 34 per cent consume at home and where socio-cultural ceremonies are being conducted or other places including hotels (Table 7).

The frequency at which respondents purchase chicken for consumption ranges from daily up to only during annual festivals. About 40 per cent of the respondents consume chicken once per month and only about 13 per cent consume more frequently than once per month. About 46 per cent consume less frequently than once per month or only during festivals. Comparison with consumption of meat from other sources (beef and small ruminants) has shown that consumption of chicken meat is quite lower than meat from cattle and goats but higher than meat from sheep. Consumption of beef at a frequency of once or less per week is reported by about 24 per cent of the respondents, while about 53 per cent were consuming only during festivals or at frequency of less than once per month. Consumption of meat from goats is also better in that about 25 per cent consume goat more frequently than once per week. The majority (about 76 per cent) of respondents consume sheep meat only during festivals and less frequently than per month.

Almost all purchase of chicken meat by a household is in a form of live chicken, as opposed to purchase of beef which is in kilos or through traditional sharing arrangements. In the majority (about 61 per cent) of the cases goat and sheep meat is purchased in a form of live animals to be slaughtered per household or to be shared between households.

Table 8. Quantity of chicken purchased at once

	No. of chicken purchased					
Site	1	2	3	4	5 and above	Total
Guba district	23	5	3	4	1	36
Gilgel Beles town	2	3	0	2	2	9
Wembera district	22	3	1	2	6	34
Dibate district	15	11	1	4	2	33
Total	62	22	5	12	11	112
Per cent	55.4	19.6	4.5	10.7	9.8	100

Theaverage number of live chicken purchased at once by households is 2 chicken (Table 8). For beef about 42 and 47 per cent of purchased amount ranges from 0.5 to 3.0 kg 3.5 to 6 kg respectively (Table 10). The quantity of egg purchased varies from 1 to more than 13, the average being about 8 eggs (Table 9).

Table 9. The amount egg purchased by respondents at a time

Site	Number of eggs purchased at a time					Total
	1-3	4-6	7-9	10-12	13 and above	
Guba district	2	4	2	8	8	24
Gilgel Beles town	0	2	1	2	4	9
Wembera district	4	4	5	10	6	29
Dibate district	4	6	5	6	2	23
Total	10	16	13	26	20	85
Per cent	11.8	18.8	15.3	30.6	23.5	100

Table 10. The amount of beef purchased by respondents at a time

Site	Quantity of beef (Kg) purchased at once					
	0.5-3	3.5-6	6.5-9	10-12	13 and above	Total
Guba district	17	18	1	0	0	36
Gilgel Beles town	8	0	0	1	1	10
Wembera district	11	13	1	2	0	27
Dibate district	8	16	6	0	1	31
Total	44	47	8	3	2	104
Per cent	42.3	45.2	7.7	2.9	1.9	100

About 72 per cent of respondents have preference for chicken of a specific age. Other additional criteria for choice of chicken are plumage colour and size. The choice for chicken with certain plumage colour by consumers could be the reason for considering this trait as selection criteria by producers in some other areas of Ethiopia (Fisseha, 2009; Addisu et al., 2014) and also for price variation based on plumage color. Similarly importance of color in making choice of poultry has been reported for chicken in Fogera woreda (Bogale, 2008).

Unlike in other reports of Ethiopia (e.g. Abbey, 2004; Fisseha and Tadelle, 2010) comb type didn't appear as a major criterion for choice of chicken in the current study. For eggs about 87 per cent of respondents have preference for eggs of specific attributes (e.g. size, egg shell colour etc). In the majority (97%) of the cases the choice is mainly for large eggs with no significant difference between districts. Additional criterion is egg shell colour where about 65 per cent of consumers make choice based on egg shell colour.

Preference for parts of chicken carcass was observed among the respondents. Of parts of chicken carcass drum stick (93.3%), side breast (*melalacha, 79.8%)*, fore breast (*feresegna*, 80.1%), wing and gizzard (54.6%) are highly preferred. Higher preference for leg parts of chicken has been reported by Kyarisiima et al.(2011) for consumers in Uganda. Consumption of neck, head, blood, digits and intestine is reported by 86.5, 58, 22, less than 2, and 14 per cent of the respondents, respectively. About 55 per cent of respondents, in addition to chicken, consume other poultry species. In Guba and Dibate districts consumption of poultry other than chicken is more common as compared to in Wenbera district and Gilgel Beles town. The difference between districts approached ($p<0.07$) but didn't reach significant level. The most common poultry other than chicken is guinea fowl which is mostly obtained from the wild and semi-domesticated in some cases. The same holds true for consumption of eggs from poultry other than chicken with more than fifty per cent of the respondents consuming such eggs. Dibate district is where the largest consumption of eggs, mostly from guinea fowl, occurs.

Eighty-three per cent of the respondents indicated the presence of culture that encourages chicken consumption. There is no significant difference between districts in this regard (Table 11). Similarly Aklilu (2007) have reported the cultural importance of chicken consumption. The main cultural activities that favor consumption of chicken include festival feasts, feeding women after delivery, gift to relatives to be visited and spiritual purpose. Similar culture also favors the consumption of egg but with significant variation between districts (Table 11). Less than 3 per cent of the respondents indicated presence of culture that prejudices consumption of chicken meat but for egg the per cent was about 25 with significant ($P<0.01$) difference between districts (Table 12) and there is difference along the gender line. It is believed that egg consumption by married women will make them awkward with consequences such as causing them to break containers they fetch water with or to become ill, particularly if she eats egg while she is in her husband's house (consumption is possible when she visits her relatives). This is particularly common in Gumuz ethnic group.

Table 11. Presence of culture that favors consumption of chicken meat and egg

Site	Presence of culture favoring consumption of chicken							
	Egg				Meat			
	Yes	No	Total	Pearson χ^2	Yes	No	Total	Pearson χ^2
Guba District	16	19	35	10.226*	29	7	36	1.073 NS
Gilgelbeles town	9	2	11		11	1	12	
Wembera district	26	9	35		29	7	36	
Dibate district	16	18	34		29	5	34	
Total	67	48	115		98	20	118	
Per cent	58.3	41.7	100		83.1	16.9	100	

NS P=0.784 *P<0.05

Table 12. Presence of culture that discourages consumption of chicken egg

Site	Presence of culture discouraging chicken egg consumption		Total	Pearson Chi-square
	Yes	No		
Guba district	9	27	36	15.198**
GilgelBeles town	0	11	11	
Wembera district	4	31	35	
Dibate district	16	19	35	
Total	29	88	117	

**=P<0.01

Chicken stew preparation is the most common type of chicken meat preparation followed by either frying or boiling. About 28 per cent prepare chicken only in a form of stew while 50 per cent prepare either as stew and fried or boiled. The difference between districts is significant (p<0.01). In about 3 per cent of the cases after making stew, boiling or frying it will be baked into bread after mixing with dough from cereal and traditionally named as *Doro dabo*.

In more than 80 per cent of the cases no preservation of chicken meat is practiced. Those who practice preservation mainly use cooling with smoking, drying, mixing with salt and lemon being exercised under rare cases and only for preservation for a few days. Storage of egg is commonly done in straw or in grain or in baskets (with or without straw). Use of cooling is practiced in less than nine per cent of the cases.

About 37 per cent of respondents keep chicken for food only, 23 per cent for food, cultural (spiritual), breeding and generating cash income. Similarly egg is produced for food only in 45 per cent of the cases and in the other cases egg is produced in addition to its food value for medicinal, cultural, cash income and breeding purpose.

In terms of meat quality of chicken about 96 per cent prefer its tenderness while about 37 per cent look for juiciness in chicken meat. Respondents rate chicken meat second to small ruminant meat in terms of tenderness followed by beef. About 83 per cent of the respondents also look into fattiness in chicken meat while about 85% do look for flavor. In terms of fattiness respondents rank chicken meat next to small ruminant and beef while in terms of flavor chicken meat is rated first by the majority (about 55%) of respondents. About 86 per cent look for colour of meat while about 52 per cent look for aroma. Colour wise respondents ranked chicken meat next to beef and small ruminants. Aroma of chicken meat is ranked next to small ruminant meat. About 67 per cent of the respondents prefer colour of egg from indigenous chicken while 60 per cent also prefer yolk colour of egg from indigenous chicken. In terms of size 57 per cent of the respondents preferred egg from exotic chicken as compared to egg from indigenous chicken, guinea fowl or ducks.

Table 13. The reaction of respondents in Metekel zone to increase in chicken price

Site	continue to purchase chicken even if price increase		Total	Pearson Chi-square
	Yes	No		
Guba district	32	3	35	7.796^{NS}
Gilgel Beles town	7	4	11	
Wembera district	30	4	34	
Dibate district	28	6	34	
Total	97	17	114	

NS= P>0.05

About 85 per cent of respondents affirmed that they would continue buying chicken even if the price increases above the current level (Table 13). No significant difference was observed between districts. About 14, 39 and 39 per cent are willing to pay 50 to 75, 76-100 and 101 to 150 birr, respectively.

About 63 per cent are willing to continue to buy and consume egg even the price increases. Currently about 84 per cent are willing to pay 2 to 3 birr per egg. With regard to the proportion of income that goes for food purchase about 13.4, 34.8, and 36.6 per cent use one-fourth, one half and three quarter of their income, respectively, for food.

Average annual chicken meat consumption per household was about 8.5 (SD=3.48) chicken with no significant (P>0.05) difference between districts. Frequency of annual chicken meat consumption for both adult male and females was found to be similar. This level of consumption is higher than the level of consumption reported for three areas of Tigray in Northern Ethiopia (Aklilu, 2007).

Monthly household egg consumption ranges from 1 to more than 16 with average of more than 10 eggs (Table 14). Average monthly consumption of adult males and females is 8 (SD=9.24 for male SD=9.67 for female) eggs and there is high variation. This level of egg consumption is also higher than reported value for consumption in Tigray (Aklilu, 2007). In addition to differences arising from various causes the variation in consumption level could also be accounted for by the difference in time.

Table 14. Household egg consumption of respondents across the four districts

Site	Household monthly egg consumption				Total	Pearson Chi-square
	1-5	6-10	11-15	Greater or equal 16		
Guba district	4	11	6	10	31	17.369*
Gilgel Beles town	1	1	0	6	8	
Wembera district	7	10	7	9	33	
Dibate district	10	7	0	8	25	
Total	22	29	13	33	97	

*=p<0.05

Conclusion

Significant sources of poultry consumption in Metekel zone include market and production at home, implying that poultry (meat and egg) consumption can be improved through addressing aspects of the market and production. With about 87per cent of the respondents consuming chicken meat at a frequency of less than once in a month the current level of poultry consumption in the area appears to be low and behind consumption of goat meat and beef. Price wise chicken meat appears to be either cheaper or equivalent to beef and goat meat. Promotion of consumption of poultry needs to be given attention in the area. There is sizeable preference for meat and egg from indigenous chicken and this creates opportunity towards promotion of indigenous chicken through improved management and genetic improvement, hence contributing to their conservation and sustainable utilization. Sizeable proportion of the respondents indicated presence of culture which prevents consumption of egg particularly by women. In the area covered by the current study the ease of availability of egg at household level appears to be better than other sources of quality protein. Given the importance of improved nutrition for women, awareness creation to change the cultural perception and improve consumption of egg by women, particularly in the Gumuz ethnic group deserves attention. Preference for various parts of chicken carcass has been identified in the current study along with use of almost all parts of a chicken carcass by sizeable number of respondents. Marketing system that may meet this need of the consumers (buying parts based on ones' own means and preference) need to be developed in the future. The information in this study, along with information on production system and marketing aspect of poultry in the area, should be used to undertake poultry development and improvement in the area.

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Lifetime Performance of Pure Jersey Dairy Cattle in the Central Highlands of Ethiopia

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Abstract

The ability of the cows to produce and reproduce for many years is a desirable characteristic. The aim of this study was to evaluate lifetime performance of pure Jersey dairy cattle at Adea Berga Dairy Research Center in the central highlands of Ethiopia. The General linear model (SAS ver. 9) was used to estimate the effect of fixed factors. Overall 3015 productive and reproductive performance records were used. The results of general linear model revealed that lactation milk yield and lactation length were significantly affected by year and parity (P<0.001). However, calving season did not have significant influence on lactation milk (P>0.05). The overall mean herd life of pure Jersey in the present study was 1813.76± 40.18 days (4.97 years). The least square mean of calf crop was 3 and 20 percent of the pregnancies were lost either by abortion or still birth. The least square mean of lactation milk yield and lifetime milk yield were 2155 kg (in 336 days lactation length) and 7216 kg, respectively. The results indicate that Jersey cows under the particular management of Adea Berga farm produced reasonable amounts of milk and length of herd life was high. Data and results of this study can provide the basis for improvement on farm selection of cows and young bulls for the national artificial insemination center (NAIC).

Keywords: herd life, lifetime milk yield, cattle, Jersey, Ethiopia

Introduction

In Ethiopia, the genetic improvement of dairy cattle is mainly based on cross breeding and adoption of improved exotic breeds. Even though there is a concern about adaptation of pure exotic dairy cattle to tropical environment (climate, feed and disease challenge), pure Friesian and Jersey dairy breeds have been raised by large scale private and state dairy farms in Ethiopia. Improved exotic breed would potentially serve selected niches in milk supply and have been also used as a genetic pool for the national artificial insemination center (NAIC) to recruit AI bulls for genetic improvement program in the country. Million and Tadelle (2003) reported 3183 kg milk yield in 362 days lactation length for Holstein Friesian cows in Debrezeit area of Ethiopia.

However, there is limited information on performance of pure Jersey breed in Ethiopia. Research reports in the tropics revealed that Jersey cows are characterized by small body size, hardy and adaptable, low maintenance requirement, high feed conversion efficiency, high milk fat content, and good reproductive performance and has been selected for tropical research and development programs (Njubi*et al*., 1992; Cunningham and Syrstad, 1987). Thus they could be a good alternative in Ethiopian highland environment to use as an additional option for intensive and large scale dairy farms as well as genetic pool for genetic improvement activities. Having information on performance of pure Jersey cows in Ethiopia will help to suggest the future genetic improvement options for this herd as it is being managed as a bull dam station and dairy research farm. The aim of this study was therefore to evaluate the lifetime performance of pure Jersey dairy cattle at Adea Berga Dairy Research Center in the central highlands of Ethiopia.

Materials and Methods

Description of the study area

This study was conducted at Adea Berga Dairy Research Center in West Shewa Zone of Oromia Regional State of Ethiopia. Adea Berga wet land is situated in the central highlands of Ethiopia at 9^0 16’ N latitude and 38^0 23’ E longitude, 70 km West of Addis Ababa and 35 km North West of Holetta on the main road to Muger. It lies at an altitude of 2500 meter above sea level. It is characterized by cool sub-tropical climate with the mean annual temperature and rainfall of 18^0C and 1225 mm, respectively (HARC, 2010). The vegetation is mainly composed of perennial grasses and sedges. Clovers, Pennisetum and Andropogon are the most common species dominating the pasture in the area.

Description of the farm and data sources

Adea Berga Dairy Farm was established at Adea Berga wetland in 1986 for commercial milk production under government state farms by using 400 introduced pure Jersey pregnant heifers and two sires (foundation stock) from Denmark. The farm had been engaged in the production and rearing of pure Jersey breed from imported foundation stock for milk production by the dairy development enterprise and also serving as a bull dam station for the National Artificial Insemination Center (NAIC). Then it was transferred to Holetta Agricultural Research Center for genetic improvement research program since 2007.

The data for this study was obtained from long-term records of pure Jersey breed that has been kept for dairy production in the farm. Recorded data for the last 24 years (1986-2010) on production and reproduction were used for this study.

Herd management

Herds are managed separately based on sex, age, pregnancy and lactation. Calves were allowed to suckle their dam until 5 days to obtain sufficient colostrum and then separated from their dams and offered fresh milk twice a day for about 6 months. Cows and heifers were allowed to graze natural pasture for about 4 hours a day and supplemented with hay and concentrate feeds up on return to barn during dry and small rainy season. However, all animals were restricted from grazing and managed indoor during main rainy season. There was regular over flood of river in the pasture land as a result of heavy rains during this period and the farm has a regular plan to harvest and stock up hay for dry and short rainy season supplementation. Calves less than 6 months, bulls and late pregnant cows and heifers were usually isolated and managed indoor.

All animals were supplemented with hay and concentrate feeds. The concentrate was usually composed of 60% wheat bran (sometimes with wheat middling), 38% noug seed cake (*Guizotia abyssinica*) and 2% salt. The amount consumed is not exactly known, since it depends up on the amount of feed available on stock. Milking was done twice a day at equal interval and the milk produced by each cow was measured and recorded on prepared format immediately after milking. Routine vaccination was conducted against Blackleg, Anthrax, Pasteurellosis, Foot and mouth disease (FMD) and Lumpy Skin Disease. Animals were de-wormed against internal parasites and treated against other infectious diseases by tentative diagnosis.

Breeding program

Pure breeding program was carried out starting on imported foundation stock of 400 pregnant heifers and two sires. Controlled mating program was practiced using both natural mating and artificial insemination. Mating was continuous and practiced throughout the year. NAIC rarely introduce new exotic Jersey semen since this farm has been used as a bull dam station for semen production to dispatch Jersey semen for national crossbreeding activities. Thus, very few young bulls were recruited based on dam performance and physical conformation for NAIC semen collection and on station breeding activities through natural mating. The rest of the male calves were culled from the farm at an early age. The mating date and sire identification number were recorded on herd book for every insemination and then transferred to cow's individual card.

Data analysis

A retrospective type of study was conducted to evaluate lifetime performances of the cows. Data was categorized into disposed cattle record to evaluate lifetime traits and pooled records (available herd and disposed) to estimate their productive performance. General linear model (GLM) least square for quantitative trait and chi square tests for qualitative trait were used to analyze the fixed effects (SAS version 9, 2002). The fixed effects fitted were animal group (imported and farm bred; farm bred animals were the progeny of imported animal that were raised in the farm), year period (grouped in to 5-7 classes based on birth and calving years. each year period represent three years), season; grouped in to three classes, based on pattern of annual rain fall distribution as dry period (October to February), light rain (March to May) and main rain (June to September), Parity (grouped in to eight classes 1,2,3,4,5,6,7and 8+).Lactation records of eighth and above parities were pooled. Preliminary analysis showed that interaction effects of the fixed factors were not significant and thus not included in the model. The statistical model is described as follows:

Experimental Models

1. Lactation milk yield and lactation length

   $Y_{ijkl} = \mu + Y_i + C_j + S_k + P_l + e_{ijkl}$

   Where, Y_{ijkl} is milk yield and lactation length trait;

   μ is the overall mean; Y_i is the fixed effect of i^{th} year period of birth;

   C_j is the fixed effect of j^{th} year period of calving;

   S_k is the effect of k^{th} season of calving;

   P_l is the effect of l^{th} cow parity;

   e_{ijkl} is random residual term.

2. Lifetime traits (Herd life, lifetime milk yield, calf crop)

   $Y_{ijk} = \mu + Y_i + S_j + G_k + e_{ijk}$

   Where, Y_{ijk} is the life time traits; μ is the overall mean; Y_i is the fixed effect of i^{th} year period of birth; S_j is the fixed effect of j^{th} season of birth; G_k is the fixed effect of k^{th} animal group; e_{ijk} is random residual term.

Results and Discussion

Lactation milk yield (MY)

Increasing milk production is the ultimate goal of dairy sectors to attain milk self sufficiency and to maximize the profitability of dairy industry. Thus, most genetic improvement programs of developing countries have focused on improving production performance of dairy cattle. Results of the least squares means and standard errors for fixed effects of birth year period, calving year period, calving season and parity are summarized in Table 1. The overall lactation milk yield and lactation length of pure Jersey cows were found to be 2154.99±16.40 kg and 336.17± 2.35days, respectively.

The result obtained in this study (2154.99 kg) similar to the reports of Yosef (2006) and Lateef *et al.* (2008). They found lactation milk yields of 2200 and 2229 kg for Jersey cattle in Ethiopia and Pakistan respectively. On the other hand, Njubi *et al*. (1992) reported a milk yield ranging from 1257kg to 1788kg for Jersey cattle per lactation which was lower than the figure obtained in the current study. The result of this study is lower than the finding of Borland and Moyo (1996) who found 3504 to 5141 kg lactation milk yield in Zimbabwe. This might be due to difference in climate and animal management.

Calving year period and parity had significant effect on MY ($p<0.0001$), but birth year period and calving season did not have significant effect ($p>0.05$). Trend of lactation milk yield associated with period of calving had no clear pattern. This could be attributed to the inconsistent management practices across years and cows were not fed according to recommended amount. However, some progressively increasing trend observed in lactation milk yield over the period of calving is an indicative of improved management and adaptation of this breed to the prevailing environment through time. Low performance of cows which calved in between 1991 and 1993 could be related to financial problems of the farm to avail sufficient feed due to regime change as this farm was funded by government. The pregnant heifers imported for foundation stock gave their first calf in between 1988 and 1990 and their milk yield was lower as compared to other calving period. This might be attributed to adaptation problem as the animals were exposed to new environment which could create more difficulty to express their genetic potential. Sendros *et al*. (2004) noted that year and parity had significant effects on lactation milk yield of crossbred cows in Holetta station, Ethiopia which agrees with the present finding. Similarly, reports from Kenya showed that mean milk yield performance of Jersey breed declined from 2,200kg in the 1960s to about 1500 kg in the 1980s (Njubi *et al*., 1992).

Analysis of variance of this study revealed that lactation milk yield significantly differed among parities ($p<0.0001$). Lactation milk yield seems linearly increasing from 1st to 5th parity. But Milk yield recorded at 2nd parity was greater than that of 3rd parity which is contradictory with several literatures. This could be due to lactation stress of first and second lactation. The lactation milk showed a declining trend after the 5th parity. Similar observations were reported by several authors (Million *et al*., 2004; Yosef, 2006, Lateef, 2007; Njubi*et al*., 1992; Million *et al*., 2010). Amimo *et al*. (2007) and Amani *et al*. (2007) also found that Ayrshire and Friesian cows attained their peak milk yields at the 4th parity. Season of calving did not have a significant effect on lactation milk yield in the present study.

Table1. Least square means and standard error of milk yield and lactation length for fixed effects of birth year group, calving year group, calving season and parity

Effect	Variable		
	N	Milk Yield (kg)	Lactation length (days)
overall	2658	2154.99± 16.40	336.17±2.35
Birth year group		NS	***
1985-1987	1193	2240.53±85.55	353.45±12.28[a]
1988-1990	266	2184.90±73.23	331.94±10.51[b]
1991-1993	168	1994.84±74.69	314.08±10.72[b]
1994-1996	362	2143.33±63.52	312.24±9.12 [b]
1997-1999	335	2099.71±86.25	327.56±12.38[ab]
2000-2002	189	1977.71±133.5	326.31±19.17[ab]
2003-2005	145	1872.04±169.5	355.86±24.33[ab]
calving year group		****	****
1988-1990	751	1759.19±166.20[d]	275.15±23.86[c]
1991-1993	374	1395.22±138.10[e]	337.05±19.83[ab]
1994-1996	301	2253.34±111.84[ab]	348.42± 16.06[ad]
1997-1999	327	1995.64±79.21[cd]	318.71± 11.37[be]
2000-2002	344	2212.04±59.07[b]	319.59± 8.48[bcd]
2003-2005	291	2526.09±64.35[a]	331.69± 9.23[ab]
2006-2008	223	2229.06±94.89[bc]	355.60± 13.62[ae]
2009-2010	47	2215.77±155.22[bcd]	366.87± 22.28[ab]
Calving season		NS	NS
Dry	1380	2101.30±46.89	329.71±6.73
Short rain	595	2066.49±54.41	333.70±7.81
Main rain	683	2052.07±50.6	331.47±7.26
Parity		****	****
1	803	2066.61±41.21[b]	354.46±5.92[a]
2	649	2362.63±41.09[a]	355.24±5.90[a]
3	442	2073.02±47.34[b]	323.11±6.80[b]
4	309	2262.08±57.72[a]	349.85±8.29[a]
5	190	2302.98±75.85[a]	350.00±10.89[a]
6	127	2005.48±94.25[b]	314.15±13.53[bc]
7	73	1985.88±125.2[b]	323.99±17.97[ab]
8	65	1527.66±141.1[c]	282.28±20.26[c]
CV		39.24	36.11

N= Number of observation, **** =p< 0.0001 ***= p< 0.001 NS (not significant) = p> 0.05
Least squares means with same superscript in the same fixed effect indicate non significance.

Herd life

Herd life refers to the period from first calving to culling of a cow from the herd. The ability of the cows to produce and reproduce for many years is a desirable characteristic. Longer herd life maximizes profit for producers as it creates more opportunity for additional herd replacements if the farms need expansion otherwise reduce the cost of replacements and more milk production over an extended period of time.

The overall mean herd life (HL) of pure Jersey in the present study was 1813.76± 40.18 days (4.97 years). The value of this study is similar to the figure reported for Holstein cows (5 years) in Slovenian**(**Janžekovič*et al.*, 2009), but higher than the value reported for Simmental cows (4 years) in Croatia (Sonja and Nikola, 2011) and Slovak(Strapák *et al.*, 2011).However, the result of the present study is lower than 6 years reported for Holstein and 8 year for Jersey in Pakistan (Teodoro and Madalena, 2005**),** 6 years for crossbred in Ethiopia (Gebregziabher and Mulugeta, 2006) and 7 years for 75 % European inheritance crossbred in Ethiopia (Kefena *et al*., 2004). The difference in HL observed in the present study as compared to the estimate of several literatures could be due to environmental difference in which the cows were maintained. Birth year, birth season and animal group did not have significant effect on HL (Table 2)

Lifetime milk yield (LTMY)

Table 2 shows the lifetime milk production performance of Jersey cows. The overall least square mean lifetime milk yield was found to be 7216.34 ± 189.83kg in 2670.97±40.21 days' total life (1813.76± 40.18 days herd life). The LTMY noted in the present study is higher than the value reported for Friesian (6021kg) and Jersey cattle (3699kg) in Pakistan (Lateef, 2007). Sreemannarayana *et al*. (1996) also estimated lower lifetime milk yield for Ongole (4567kg) and Jersey x Ongole crossbred cows (6372kg). The value obtained in this study is also higher than the report of Aynalem *et al*., (2011) who found 6309 kg for 62.55% exotic cross, 7122 kg for 75% exotic cross and 5820 kg for 87.5%exotic cross in Ethiopia. On the contrary it is lower than 11912 kg for Friesian cows which kept under high level management in Venezuela (Rizzi *et al*., 2002) and 7998 kg for 50% F_1 crossbred in Ethiopia (Aynalem *et al*., 2011). These indicated that the performance of Jersey cows was comparable with crossbred cows in the tropical environment. However, the lower LTMY of Jersey cows observed in the present study as compared to European counterpart probably indicated that the management level, in which this temperate breed had been kept, was not sufficiently supporting the cows to express their genetic potential. Similarly it can be noted that less effort has been done in the last years to improve their genetic potential.

Table2. Least square mean and standard error of herd life and lifetime milk yield

Effect		Variable	
	N	Mean ± SE HL (days)	Mean ± SE LTMY (kg)
Overall	680	1813.76±40.18	7216.34±189.83
Birth season		NS	NS
Dry	422	2017.32 ± 318.64	7211.89 ± 1505.26
Short rain	82	2069.58 ± 338.12	7352.89 ± 1597.30
Main rain	176	2164.53 ± 327.38	8251.95 ± 1546.54
Birth year period		NS	***
1985-1987	369	1426.63 ± 530.25	7144.07 ± 2504.91[ab]
1988-1990	91	2173.30 ± 541.79	5856.17 ± 2559.45[b]
1991-1993	41	2326.93 ± 553.26	8111.77 ± 2613.60[a]
1994-1996	96	2175.43 ± 540.06	8048.88 ± 2551.25[a]
1997-1999	83	2316.76 ± 528.33	8867.00 ± 2495.85[a]
Animal group		NS	NS
Imported	370	2544.54 ± 844.67	7103.87 ± 3990.22
Farm bred	310	1623.08 ± 220.12	8107.29 ± 1039.86
CV		57.77	68.60

N= number of observation, **** =p< 0.0001 ***= p<0.001 * = p< 0.05, NS (not significant) =p>0.05)

Least squares means with same superscript in the same fixed effect indicate non significance.

Lifetime calf crop

The overall least square mean and standard error of lifetime calf crop of pure Jersey cows in the present study was 3.22±0.07. The result is closer to the value (3.5) reported for Boran and Boran x Friesian crossbred (Gebregziabher and Mulugeta, 2006) and 3.6 reported for synthetic dairy cow in Alberta, Canada (Arthur *et al*., 1993). But it is lower than the value (5.2) reported for pure Horo, and 4.5 reported for Horo x Simmental crossbred in Bako research station in Ethiopia (Gebregziabher and Mulugeta, 2006). The lower estimate of calf crop in the present study was probably due to higher abortion and still birth (20.08%) incidence in the farm. The result of present study revealed that calf crop was significantly affected by birth year period and birth season (p< 0.05). However, animal group did not have significant effect on calf crop (p>0.05).

Abortion and still birth

Abortion refers to loss of fetus at less than 260 days of gestation. Whereas calf that born dead between 260 days and full term is considered as stillbirth. A full term delivery or completed gestation is considered as normal delivery. The overall frequencies of normal delivery, abortion and still birth are 79.93%, 13.20% and 6.88%, respectively. Generally the result of the present study revealed that 20 percent of the pregnancies were lost either by abortion or still birth. The frequency of abortion recorded for Jersey cattle in this study is substantially higher than 3 to 5% which is considered tolerable in dairy farms (Kirk, 2003; Hovingh, 2009). Sreemannarayana *et al*. (1996) also reported 6.4% and 7.3%incidence rate of abortion in Ongolo and crossbreds, respectively which is also lower than the current finding. On the contrary frequency of abortion (13.20%) recorded in this study is similar with the value (13.60%) reported for Boran cows at Abernosa ranch in Ethiopia (Ababu, 2002). However, it is lower than 17.6% reported for Boran x Friesian herd maintained at Chefa state farm in Ethiopia (Gebeyehu and Hegde, 2003).

Conclusion and Recommendation

The overall results indicate that Jersey cows under the particular management of Adea Berga farm produced reasonable amounts of milk and had longer herd life. It was noted that the significant effects of years and seasons indicate inconsistent management across the years and seasons. Data and results of this study can provide the basis for improvement on farm selection of cows and young bulls for the national artificial insemination center (NAIC).The need of feeding and animal health intervention is essential to reduce the environmental stress. Since the farm is being used as genetic pool to recruit bulls for crossbreeding activities, better breeding schemes should be designed for further improvement of performances.

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Least Cost Production and Evaluation of Multi-Nutrient Block for Lactating Crossbred Dairy cows Fed on a Basal Diet of Oats Straw

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Abstract

The activity was initiated with major objective to replace cost inducing agro-industrial by-products in the conventionally recommended urea-molasses multi-nutrient block (UMMB) with locally available cheap feed resources. Economic analysis was conducted to know cost of production of the blocks and the cost-benefits incurred in supplementing the control and the various treatment blocks to lactating crossbred cows fed on a basal diet of oats straw. Replacing cement with lime as a binding agent on partial or complete bases (W/W) did not maintain block physical hardness and consistency. On the other hand, partial (50%) replacement of cement by clay soil as a binding agent worked out very well. Partial replacement (W/W) of the crude protein (CP) in the control block by CP obtained from locally available, cheaper conventional and non-conventional sources resulted to decreased CP concentrations in the treatment blocks compared to control blocks. Production cost/kg of the UMMB indicated that the newly manufactured blocks have better comparative advantages over the control block. Feed intake was highly variable; however, there is no noticeable change (P>0.05) between the control and the new blocks for daily total dry matter and basal feed intake. The daily amount of block and CP intake was lower for cows supplemented with a poultry litter based block. Daily milk production was also similar among all the cows except those supplemented with a poultry litter based UMMB that produced inferior milk compared to control cows. Furthermore, cost-benefit analysis indicated that there was in general little or no difference in daily profit obtained from cows on the control and treatment blocks. It is hence, recommended that partial replacement (W/W) of the costly agro-industrial byproducts with locally available/produced feed resources and binding agents pay off without a compromise in the daily performance of lactating crossbred cows.

Introduction

Grazing and crop residues constitute the major livestock feed resources in the central highlands of Ethiopia. These feeds are characterized by an imbalanced array of nutrients, of which fermentable nitrogen is usually the first limiting; organic matter digestibility is also usually below 50%. In line with this, Preston (1987) reported considerably lower rumen ammonia level (<200mg/l of rumen liquor) than that required for maximum cellulose digestion in cattle and sheep grazing during the dry season in Ethiopia. To rectify the situation feeding strategy should be geared towards maximizing fibre degradability in the rumen, optimize microbial protein synthesis and promote escape of dietary protein and lipid supplements from the rumen fermentation. Supplementation with MNB is a simple and effective method of improving rumen function when the basal diet is dominated by low, poor quality fibrous materials. Besides providing easily fermentable energy and nitrogen; the block could be used as a carrier of micro-nutrients. Various reports indicated that MNB can be efficiently utilized to boost ruminant productivity (Cheva and proma, 1995; Hossian *et al*., 1995; Bheekhee *et al*., 1999). In Ethiopia as well some research has been conducted to promote it both on-station and on-farm (Michael *et al*., 1989; Tekeba *et al*. 2013). Results are in general very much encouraging although research efforts have so far been mainly focusing on quantification of biological parameters like; milk yield, feed intake and fattening potentials of the block. Though the technology involved in block making is both simple and practicable, factors such as ingredients used, mixing techniques and environmental factors affect the block stability. The state of hardening is of particular interest from the point of view of transportation and consumption by the animals. Moreover, the accessibility and sky-rocketing prices of major ingredients in the block (urea, oil seed cakes, wheat bran and cement) posed negative setbacks in the dissemination of the block for wider use. It can be said that no emphasis has so far been given to address the problems. Consequently, an investigation was carried out to study the biological and economic feasibility of manufacturing least cost multi-nutrient block leaks from locally available feed resources and that which can be fed to ruminant animals maintained on low quality basal feed resources.

Materials and Methods

The study site

The trial was conducted between 2008 – 2010 at Holetta Agricultural Research Center. The center is located at about 30 km west of the Addis Ababa along the main road to Ambo.

Percentage compositions of feed ingredients in the blocks

The control block used in the trial was the one previously tested on-station and promoted to users via extension and development related research works. Least cost intervention blocks had their major agro industrial byproducts partially or completely replaced (W/W) by locally available cheaper, non-conventional feed ingredients. The new ingredients that replaced urea in the least cost blocks were: dried and powdered tagasaste leaf, air dried poultry litter and brewery dry grains. Similarly, the wheat bran in the former control block was replaced by ground pod of *Prosopis juliflora*. Similarly, clay soil and lime (powdered calcium carbonate) was used as binding agent instead of cement in the newly formulated and manufactured blocks. Either partial or complete replacement was made by weight basis (W/W) for each ingredient used in the manufacturing of the least cost blocks. In general, sixteen different combinations were tested against the control block (F1) for their efficacy using various evaluation techniques that involve steps ranging from testing block physical strength to animal response trials using lactating crossbred dairy cows.

Table 1. Percentage compositions of ingredients used in making the feed blocks

Ingredients	Block manufacturing Formulae (% basis)																
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17
Molasses	36	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Wheat bran	25																
Prosopis j.		25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Urea	10	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Noug cake	13	6	6	6	6	6	6	6	6					6	6	6	6
Tagasaste		11	11	11	11					17	17	17	17				
PL						11	11	11	11								
BDG														11	11	11	11
Salt	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
M. mix	3																
Cement	10	5		5		5		5		5		5		5		5	
Lime				5	10			5	10			5	10			5	10
Clay soil		5	10			5	10			5	10			5	10		
Total %	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

PL=poultry litter; BDG=brewery dry grain; M.mix=mineral mix; F1=control block

The procedures that were adopted to mix up the experimental ingredients were as shown through step 1to5 below.

1. Urea was mixed thoroughly with molasses for about 20 minutes
2. Salt, mineral mix and biding agents (cement, soil, lime) were added and mixed in to 0.6lt of water
3. Ingredients under items 1&2 were thoroughly mixed
4. Similarly, protein sources (noug cake, poltry littre, brewery dry grains, dry tagasaste leaf) were mixed to item 3 above
5. The energy sources (wheat bran, *Prosopis juliflora* pod flour) were added and mixed in to item 4 above. The paste was then molded in to a block which was made to be properly dried in the air and under shade.

Table 2. Chemical compositions and In-vitro digestibility of individual feed ingredients used in manufacturing experimental block leak (g/kg DM)

Feed ingredient	DM	Ash	OM	CP	DOMD	NDF	ADF	Lignin
Molasses	723.5	0	0	290.0	0	37.0	NA	NA
Wheat bran	882.5	48.0	952.0	166.2	726.6	422.7	128.0	27.9
Prosopis j. pod	884.2	54.5	945.5	145.9	615..0	462.7	279.8	88.1
Urea	NA	NA	NA	NA	NA	NA	NA	NA
Noug cake	926.0	111.0	889.0	300.3	689.6	406.4	297.3	77.3
Tagasaste	917.9	49.1	950.9	225.9	680.6	576.5	378.8	53.4
Poultry litter	927.3	167.2	832.8	212.5	582.9	435.5	284.4	65.9
Brewery grain	934.4	39.2	960.8	263.9	588.2	591.2	280.0	65.5

DM=dry matter, OM=organic matter, CP=crude protein, NDF=neutral detergent fiber, ADF=acid detergent fiber, DOMD=digestible organic matter in the dry matter, NA=not analyzed

All samples from feed ingredients above were analyzed for DM, Ash, OM, and CP according to AOAC (1990) procedures. NDF, ADF and permanganate lignin were determined by the methods of Van Soest and Robertson (1985). *In vitro* organic matter digestibility was determined using the procedures outlined by Tilley and Terry (1963).

Measuring block physical hardness and consistency

Three trained personnel gave their subjective judgments about the strength of the block when the blocks were assumed to be adequately dried. The newly produced least cost blocks were then compared and judged against the control block that was used as reference block throughout the trial. Major criteria that were considered were:

1. Block strength as measured through finger print left after finger pressing and fragility test (test after a 55 kg weighing load was placed up on the dried block)
2. Block solubility test was made after submerging the block in to a bucket full of water for about 2 hours and checking whether the shape of the block remained intact or not.
3. Density of the block as measured through the volume and mass (weight) of the block up on sufficient drying
4. Average length of days taken for complete drying

Testing the block for chemical composition

All blocks were subjected to chemical analysis after representative samples were randomly taken and analyzed in the laboratory for dry matter, nitrogen, and neutral detergent fibre using standard analytical laboratory procedures.

On-Station feeding trial on early lactating crossbred cows

Blocks that were found to be similar and/or above the control using lab. chemical and bioassay techniques were promoted to feeding trial on-station. The experiment was conducted on crossbred cows (50%) of same genotypes, stage of lactation (15±8 days after parturition), live weight (352±28Kg), previous lactation performance (10-12kg/d/cow). The animals only varied in parity which ranged between 1 and 4. After the animals were adapted to leaking block for 7days, they were offered with *adlibitum* oats straw, water and treatment blocks. Concentrate composed of 67% wheat bran, 32% cotton seed cake and 1% salt offered at the rate of 0.5kg /Lt of milk production after 25% of the daily allowance for concentrate was deducted. The treatment set-up for the tested blocks is shown in the Table 3 below.

Table 3. Control and treatment blocks leak supplements used for dairy feeding trial

Ingredients	T1(Control) % inclusion	T2 % inclusion	T3 % inclusion	T4 % inclusion	T5 % inclusion
Molasses	36	40	40	40	40
Wheat bran	25	0	0	0	0
Prosopis j.	0	25	25	25	25
Urea	10	6	6	6	6
Noug cake	13	6	6	0	6
Tagasaste leaf	0	11	0	17	0
Poultry litter	0	0	11	0	0
Brewery Grains	0	0	0	0	11
Salt	3	2	2	2	2
Mineral mix	3	0	0	0	0
Cement	10	5	5	5	5
Clay soil	0	5	5	5	5
Total	100	100	100	100	100

Data collection

Types of data collected included: Block physical hardness & consistency; block chemical compositions; intake (block, concentrate, basal feed and total DM intake); milk yield and quality; all variable costs related to input and output prices are considered for calculating the cost- benefit ratio.

Statistical data analysis

While subjective judgment from an average result of three trained personnel was used to judge block strength, CRD model using SAS 2002 was used to compare the new blocks against the control using various chemical and bioassay techniques. A 5x5 simple Latin Square Design using SAS 2002 was used to analyze data set from animal response trial.

Cost-benefit ratio was computed using simple partial budget analysis.

Results and Discussions

Measuring block physical hardness and consistency

This is part of the study that ensures whether the different ingredients in a block were combined in the manner that could allow the blocks sufficiently dried so that they can easily been transported, stored and fed without any limitation in block and basal feed intakes. The result for the different parameters used to judge block hardness and consistency are indicated in Table 2 below. It should be noted that the table displays the result of only those block formulae which have already been qualified and promoted to the feeding trial based on the pre-set criteria to judge the strength and consistency of the newly formulated blocks against the control blocks.

Table 4. Physical hardiness of blocks as measured through the different parameters

Ingredients	Block manufacturing formulae (% basis)				
	Control block	Treatment blocks			
	F1	F2	F6	F10	F14
Molasses	36	40	40	40	40
Wheat bran	25				
Prosopis j.		25	25	25	25
Urea	10	6	6	6	6
Noug cake	13	6	6		6
Tagasaste		11		17	
Poultry litter			11		
Brewery dry grain					11
Salt	3	2	2	2	2
Mineral mix	3				
Cement	10	5	5	5	5
Lime					
Clay soil		5	5	5	5
Total %	100	100	100	100	100
Block strength					
a. finger press	G	G	G	G	M
b. Fragility	G	G	M	M	M
Block solubility	G	G	M	G	M
Density(kg/m^3)	826	690	650	670	620
Drying duration (h)	72	96	96	96	120

PL=poultry litter; BDG=brewery dry grain; M.mix=mineral mix; G=Good, M=medium,

Block physical strength

It was measured by observing finger print that have been left after finger pressing and fragility test after a 55 kg weighing person was allowed to stand on the dried block. This was done for 4 replicated blocks per treatment from day one to three after the blocks were molded and allowed to dry under shade in a three sided opened shelter. Compared to the control block the newly formulated and manufactured blocks maintained their physical hardness and consistency when cement was only partially replaced (50%) by clay soil **(**Table 2**) i**ndicating that the ingredients used were held together reasonably well and that they did not crumble thereafter and were therefore not crushable. This has the advantage of ensuring transportation over long distances and storage of such blocks over very long periods of time. Even though, the level of molasses and binding agent have some negative relation as far as hardening of block is concerned, in the current trial the level of molasses was kept constant to see the degree of block strength by only varying the level of replacements for the binding agents. Lime did not worked well as binding agent in the current trial though there are reports earlier that hardness/strength and consistency of blocks were maintained well over cement when lime in its slaked form was used at levels ranging between 4-15% (Hassoun1989; Aarts *et al.* 1990; Hadjipanayiotou *et al.,* 1991). The inconsistency with the present finding may be attributed to the difference in the level of molasses and the type and quantity of lime used (powdered CaCO3in the current trial as opposed to CaO and Ca $(OH)_2$ in previous research works). Ordinary clay or bentonite has also proved efficient for block making (Chen *et al.,* 1993b; Guan *et al.,* 1998).Among the three binding agents, clay soil can be relatively accessed by smallholder farmers at no or low cost and hence has considerable practical significance for use under on farm conditions. The selection of the binder, therefore, has to depend upon price and availability. From the current study, however, it is difficult to conclude that complete replacement of cement by clay soil and/or both replacement levels of cement for lime did not worked out well since replacements were made only on weight basis. Moreover, all exhaustive options including levels higher than that used in the control blocks need to be cheeked.

Block solubility

Blocks were submerged in to a bucket of water for about 2 hours to check whether the shape of the block remains intact. This is also a test used to ensure gradual release of urea and molasses to provide a constant source of degradable nitrogen throughout the day to promote growth of rumen microbes in ruminants fed poor quality forage. If otherwise, urea and molasses toxicity will occur, as noted by Preston and Leng (1990). When soaked in water, the blocks for which the cement was partially replaced with clay soils did not dissolve until the end of the second hour (Table 2). It is worth noting here that for ruminants to have access to the nutrients in salt, mineral or molasses blocks, licking action with their tongues is important i.e. a sort of abrasion. Their saliva would not therefore soak the blocks, unnecessarily dissolve the nutrients and, by so doing, oversupply urea or molasses to the animals. The reason behind the relatively poor solubility of block made by partial replacement of urea with poultry litter and BDG may be associated to the higher bulk density (see density in Table 2 above) of these ingredients and the relatively smaller amount of molasses used to soak up these ingredients. In this regard, Hadjipanayiotou *et al*. (1991) indicated that blocks with poultry litter would require higher level of binding agents (>10%).

Density of the block

Density was measured by the mass (weight) and volume of the block up on sufficient drying. The density of blocks was found to decrease with increasing contents of bulky materials replacing urea and wheat bran. The density (kg/m^3) of blocks made is shown in Table 2. Block density was affected by the types of ingredients used and the method of pressing. For instance, less pressing was applied to prepare a block made by partial replacement of urea and wheat bran with various protein and energy sources resulting in the formation of less dense blocks than that of the control block. In general, the calculated density of the finished block (see Table 2) was found to be closely related to the bulk density of the ingredients used. The finding from this study is in agreement with the report of Hadjipanayiotou *et al*. (1993). In some cases, in the current trial the number of blocks produced for same kg of mix was higher for formulae where urea has been replaced fully by bulky protein sources like tagasaste leaf, BDG and poultry litter and/or when wheat bran was fully replaced by prosopis pod powder even though densities for such blocks were smaller and also that they were too delicate after several days of drying compared to the control block.

Length of days required for complete drying

Depending up on the levels of replacements used for urea, wheat bran and cement, 3 to 5 days were required for complete drying of the control and experimental blocks under shade conditions. Since the level of molasses in all except the control block was similar the difference in the duration of drying between the different treatment blocks may have been emanated from the variation in the partial replacement of the cement in the control block by clay soil. Control block attained sufficiently dried block within three days while it took 5 days for block on formulae 14. This could be attributed to the bulky nature and high contents of fiber (Table 1) which in turn led to difficulty of the molding process. Obviously, more days would have been required for adequate drying than that recommended in Table 2 above if same experiment would have been repeated during the rainy season due to the fall in temperature and relative humidity. Hardening of urea-molasses block increased with advancing drying period. However, care should be taken in drying blocks for longer period since longer drying periods would result in extremely hard blocks that could reduce block solubility and intake. It is preferred that urea-molasses blocks are made at a time prior to their use so that they would reach the desired degree of hardness at the time required. However, when long storage period is inevitable, wrapping and/or storing the blocks in polyethylene sheets/bags will maintain the desired hardness. Fortunately, no mold growth was observed in any one of the blocks even when stored for over more than two months after preparation in this study. Based on these observations, it can be inferred that the urea molasses multi-nutrient block so prepared could be preserved in a dry environment at room temperature for a reasonable period.

Nutritive values of experimental blocks

The nutritive values determined through proximate, detergent analysis and *in-vitro* digestibility of the different formula blocks are presented in Table 3 below. In general, it can be said that for all nutrient profiles, the blocks were significantly different (P<0.05) when comparison was made both among the newly manufactured blocks and/or when these blocks were compared with the control block. The control block had the highest CP (P<0.05) followed by blocks on treatment 2 & 4 where the urea has been partially replaced by tagasaste leaf and brewery dry grain (BDG). Block prepared with partial replacement of urea with poultry litter had the lowest CP. The organic matter digestibility in the DM (DOMD) of the blocks ranged from 619 g/kg in poultry litter based block to 684.1g/kg DM in blocks where urea and noug seed cake were partially replaced by tagasaste leaf powder. Blocks with tagasaste leaf powder (T2 &T4) had the highest (P<0.05) DOMD while those based on poultry litter had the lowest (P<0.05) DOMD. Metabolizable energy contents of experimental block as expressed through Mega joule per kilogram DM followed same trend as for DOMD of the blocks. The NDF contents of the blocks differed from 325.9 g/kg DM in BDG based block to 227.3 g/kg DM in the control block. The control block had the lowest (P<0.05) NDF followed by blocks on tagasaste leaf powder and poultry litter based blocks. The composition of ADF on the other hand was highest for BDG and poultry litter based blocks (P<0.05) while it was recorded to be lowest (P<0.05) for blocks on the control and tagasaste leaf powder (T2) based blocks. The lignin contents of the blocks were similar (P>0.05) for treatmet blocks. The control block had the lowest (P<0.05) lignin content of all the blocks. The difference in the nutritive value among the different experimental blocks is quite expected owning to the difference in the type and quantity of ingredients used in manufacturing of the blocks. The difference in the nutritive value of constituent feed ingredients (see Table 2 above) used in the manufacturing of each treatment block might have further influenced the nutrient profiles in the experimental blocks. Previous research workers in this regard have also reported same result (Kakkar and Makkar, 1995; Aganga, *et al*., 2005). The highest urea level and the low contents of fiber in the component ingredient feeds in the control block positively contributed to the considerably higher contents of CP and lowest contents of the fiber components. The way poultry litter has been dried and stored and the nature and type of the substances used as litter perhaps relatively affected the nutritive value of the block compared to blocks on the control and other treatments.

Table 5. Chemical compositions and *in-vitro* digestibility of supplemental block leaks

Variable (g/kg DM)	Treatment					Mean±SEM	CV%
	F1	F2	F6	F10	F14		
DM	938.3^{c}	938.3^{c}	954.0^{a}	954.4^{a}	943.8^{b}	945.7±1.41	0.21
Total ash	256.1^{b}	222.7^{d}	273.4^{a}	209.0^{e}	234.1^{c}	239.1±2.07	1.78
OM	743.9^{d}	777.3^{b}	726.6^{e}	791.0^{a}	765.9^{c}	760.9±2.07	0.56
CP	423.8^{a}	318.3^{b}	307.4^{d}	313.3^{c}	318.8^{b}	336.3±0.95	0.27
DOMD	638.1^{c}	675.6^{a}	619.0^{d}	684.1^{a}	656.6^{b}	654.6±3.35	1.71
ME (MJ/Kg DM)	10.21^{c}	10.81^{a}	9.91^{d}	10.94^{a}	10.50^{b}	10.47±1.34	1.71
NDF	227.3^{d}	263.7^{c}	293.5^{b}	279.8^{b}	325.9^{a}	243.9±4.93	9.98
ADF	117.9^{c}	168.8^{c}	210.7^{a}	189.6^{b}	213.5^{a}	188.7±3.02	4.82
Lignin	31.1^{b}	38.9^{a}	40.8^{a}	42.2^{a}	54.3^{a}	39.4±2.21	12.39

Despite partial replacement of urea in the control block by different locally available non-conventional protein sources, the drop in CP contents were not large enough to affect ideal rumen environments for fiber digestion. Whitman (1980) reported that the critical CP level to support optimum rumen function was 7%, which indicates the adequacy of CP of the supplemental blocks used in the present studies.

Daily feed and major nutrient intake

The basal roughage used for this feeding trial was oat straw collected immediately after grain harvest for seed production from on-station forage trial sites. Hence, oat straw used in the trial as any other crop a residue was of low nutritional quality it is not expected to meet production requirements of the animals. Feed intake of experimental cows maintained on a basal diet of oat straw and supplemented with the different supplemental blocks and cotton seed cake based concentrate was as shown in Table 4 below. Daily basal feed and total dry matter intake were non-significant (P>0.05) for all cows leaking the different blocks and the control block. There was no considerable change in basal feed and total feed intake associated to the change in block formulation even among the newly manufactured block leaks.

Table 6. Effect of supplemental block leak and concentrate mix on feed intake of experimental cows

Variable (kgd^{-1})	Treatment					Mean±SEM	CV%
	1	2	3	4	5		
Oat straw intake	8.00^{a}	8.06^{a}	8.14^{a}	8.20^{a}	8.16^{a}	8.11±1.05	13.63
Concentrate mix	3.32^{c}	3.41^{b}	3.54^{a}	3.41^{b}	3.55^{a}	3.44±0.42	5.32
MNB intake	0.946^{ab}	1.07^{a}	0.657^{b}	0.983^{a}	1.06^{a}	0.942±0.62	35.15
TDM intake	12.26^{a}	12.54^{a}	12.33^{a}	12.59^{a}	12.77^{a}	12.50±1.13	10.23
CP intake	1.77^{a}	1.74^{ab}	1.64^{b}	1.72^{ab}	1.78^{a}	1.73±0.45	15.30
MEI (MJ/Kg DM)	113.16^{b}	116.57^{ab}	113.62^{b}	116.94^{ab}	118.53^{a}	115.77±3.43	10.17

For details on each block formulation, see Table 3 above

Despite the observed change in the daily supplemental block and concentrate mix intake ($P<0.05$), cows on all treatment diets tended to have consumed similar amount of dry matter implying the possibility of producing blocks from whatever local feed resources available within the proximity of the small holder farmers. Moreover, it is in line with the very objective of this trial that block of same quality in terms of supporting animals' performance equal to that of the conventionally on-farm used control block could be manufactured. The absence of difference in the basal feed intake between cows maintained on the control and the newly manufactured blocks on the other hand is a reflection of the fact that the demand for ideal ruminal environment (rumen NH3-N & PH) for roughage digestion has equally been met as that for cows supplemented on the control block. In general, the overall improvement in the basal and total feed intake in the present trial could also partly be associated to the supplemental concentrate mix which was composed of an escape nitrogen source cotton seed cake and wheat bran. Improvement in the basal diet due to UMMB and cotton seed cake based concentrate mix supplementation has been well established and may vary widely depending on quality of basal feed and feeding system (Bheekhee *et al*., 2002; Singh and Singh 2003).

Experimental cows also varied ($P<0.05$) in the daily amount of nutrient they have consumed. Accordingly, experimental cows except those maintained on the poultry litter based block leak consumed similar amount of CP. The lower CP contents of poultry litter (see Table 2) might have resulted to the observed low intake. Similarly, great disparities were observed among experimental cows in terms of daily metabolisable energy intake. Consequently, cows leaking experimental block under treatments 2, 4 and 5 received greater ($P<0.05$) amount of daily metabolisable energy compared to their counter parts on the remaining blocks. It can be seen from the Table 4 above that the differences in the intakes of both nutrients among the experimental cows didn't happen to influence feed dry matter intake for the basal and total daily feed intake. The reason could be explained by the fact that all cows were on the positive CP and energy balance compared to the requirement (97.6MJ, ME/d and 866.5 gm/d of total protein) of a 352$\pm$28Kg weighing cows that daily produces 10-12Kg of milk with 5% butter fat according to Kearl (ARC, 1990). Increased intakes of dry matter, organic matter, crude protein, metabolisable energy, neutral-detergent fiber and acid- detergent fiber with UMMB lick supplementation has also been reported by several researchers (Michael et al., 1989; Mohini, 1991; Gupta and Malik, 1991)

Daily milk yield and compositions

The milk yield and composition of experimental cows are shown in Table 5. Daily milk yield, milk protein and total solids contents were shown to have significant ($P<0.05$) differences among cows supplemented with the different treatment blocks. Compared to cows supplemented with the control and other treatment blocks both daily milk yield and qualities (except fat contents) were inferior ($P<0.05$) for experimental cows leaking the poultry litter based block. Generally speaking cows supplemented with the newly manufactured blocks can be sustained equally or even considerably more than cows maintained on the control block implying additional benefits for the small holder dairy farmer from the reduced cost of block manufacturing and extra daily savings on concentrate supplementation. Comparable daily milk yield and milk compositions with cows on the control block may be explained by the fact that the ME/CP ratio of the treatment rations were balanced leading to subsequent maintenance of NH3 content in the rumen. This in turn might have led to an improved ruminal environment for micro-organisms, increased digestibility and dry matter intake of oat straw. At the same time, addition of UMMB to a rice straw based ration increased straw digestibility, feed intake, total nutrient absorption and protein: energy ratio in the nutrients absorbed (Wanapat, 1985; Preston and Leng, 1987; Leng, 1991).

Table 7. Effect of different block supplementations on milk yield and compositions

Variable (kgd^{-1})	Treatment					Mean±SEM	CV%
	1	2	3	4	5		
Milk yield	11.83^{ab}	11.64^{b}	11.39^{c}	11.99^{a}	11.89^{a}	11.75±0.63	5.10
Milk protein (%)	2.84ab	2.95a	2.71b	2.80ab	3.03a	2.87±0.55	10.34
Milk fat (%)	3.86a	3.95a	3.77a	4.26a	4.07a	4.01±0.73	13.30
Total solids (%)	12.99b	13.40ab	11.30c	13.25ab	13.78a	12.77±0.96	7.18

For details on each treatment block formulation see Table 3

Moreover, the inclusion of cotton seed cake in the concentrate mix might have helped to save the concentrate mix and satisfy the total protein requirement of experimental cows. Other authors (Leng *et al*., 1991; Singh and Singh 2003; Misra and Reddy 2004) also reported same result with cotton seed and fish meal inclusion in the ration of high yielding crossbred cows. Though differences for fat contents of the milk among experimental cows were non-significant (P>0.05) it appears that supplementation with the blocks substantially improved fat contents. These enhancements were similar to those reported by Sivayoganathan *et al*. (2001) and Misra *et al*. (2006). Comparable fat content of milk with the control group, presumably due to high acetic acid fermentation in the rumen of treatment blocks associated with increased digestibility of CF and improved energy intake. This is also in consistent with previous findings by (Sivaiah and Mudgal 1983; Sudhakar *et. al*., 2002).

Benefit-cost ratio

Cost of manufacturing and the relative advantage of the different treatment blocks over the control block are presented in Table 6 below. Calculations were based on price data set collected for each treatment block at the time of manufacturing of the blocks.

Table 8. Production cost (Eth. Birr) per kg of the different supplemental block leaks

Ingredients	Control (T1)		T2		T3		T4		T5	
	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost
Molasses	36	1.44	40	1.60	40	1.60	40	1.60	40	1.60
Wheat bran	25	0.60								
Prosopis j.			25	1.00	25	1.00	25	1.00	25	1.00
Urea	10	1.25	6	0.75	6	0.75	6	0.75	6	0.75
Noug cake	13	0.57	6	0.26	6	0.26			6	0.26
Tagasaste			11	0.07			17	0.10		
PL					11	0.11				
BDG									11	0.22
Salt	3	0.12	2	0.08	2	0.08	2	0.08	2	0.08
M. mix	3	2.40								
Cement	10	0.23	5	0.12	5	0.12	5	0.12	5	0.12
Clay soil			5	0.00	5	0.00	5	0.00	5	0.00
Labor		0.17		0.17		0.17		0.17		0.17
Total	100	6.92	100	4.05	100	4.09	100	3.82	100	4.20
% change over the control			41.47		40.90		44.80		39.31	

1 US dollar~20 Eth. Birr, BDG=brewery drain grain, PL= poultry litter, M.mix=mineral mix

Taking production cost/kg of the urea-molasses multi-nutrient block in to account the newly manufactured blocks have strong comparative advantages over the control block minimizing the cost of block manufacturing between 39 and 45% (Table 6). Block manufactured under treatment number four was produced with the least cost followed by blocks manufactured under treatment number 2, 3 and 5, respectively. The gained benefit in cost reduction, however, may not be sustained over a very long period since the cost of buying of each ingredient at any given time in Ethiopia is highly subjected to change owning to change in the seasonal availability of the ingredients. On the other hand, economic returns were calculated for the different groups of animals (Table 7). A partial budget analysis measures those items of income and expenses that change (Stemmer *et al*., 1998). Therefore, the costs of UMMB, concentrates and dry roughages were considered since all other variable costs (labor, electricity, water etc.) were the same for both the groups.

Despite differences in the cost of the different blocks manufacturing (Table 6 above) UMMB supplementation of dairy cows indicated that there was little or no difference in terms of the daily profit obtained between cows leaking the control and the newly produced blocks. The reason can be speculated to the smallest daily amount of block intake and the corresponding difference among experimental cows (Table 4) couldn't able to influence cost-benefit ratio calculations. Moreover, similar total dry matter and nutrient intakes that existed between the treatment cows and the control cows might explain the reason. Moreover, it was observed that the benefit: cost ratio was highest in T4 group (1:1.46), with a total profit of ETB 71.17/cow/day (Table 7). Compared to cows maintained on the control block profits obtained from cows leaking blocks manufactured under treatment 2& 3 were smaller by 0.4 and 2.8 ETB/cow/day . This could be attributed to the relatively lower milk production response of cows leaking these blocks.

Table 9. Economic benefit obtained from lactating crossbred cows leaking the different supplemental blocks (Eth. Birr)

Variable	Control (T1)	T2	T3	T4	T5
Milk yield (Ld^{-1})	11.83	11.64	11.39	11.99	11.89
Concentrate (kgd^{-1})	3.32	3.41	3.54	3.41	3.55
Supplemental block leak kgd^{-1})	0.946	1.07	0.657	0.983	1.06
Oat straw (kgd^{-1})	8.00	8.06	8.14	8.20	8.16
Total feed cost/cow/d	50.37	48.74	47.88	48.73	49.76
Total income/cow/d	118.30	116.4	113.90	119.90	118.9
Total profit/cow/d	67.93	67.66	66.02	71.17	69.14
% change in profit over the control		-0.4	-2.8	4.8	1.8
Benefit : cost ratio	1.35	1.39	1.38	1.46	1.39

1 US dollar~20 Eth. birr

In general, the result from the current trial is in agreement with the findings of several other authors (Leng *et al.* 1991; Singh and Singh 2003; Misra and Reddy 2004) in that the use of multi-nutrient block plus a concentrate ration mainly formulated from escape nitrogen based supplement (Cotton seed cake & wheat bran in the current trial) can help save the daily concentrate allowance by 30 to 40% without any loss in animal production. The saving from the present trial was 25%.

In view of the above, the economic returns may be higher if the positive long-term impact of supplementing the newly manufactured block leaks on general body condition and reproduction are also taken into account. Considering the present cost of feed supplement and the market price of milk, supplementation with the formula blocks was found both economical and cost effective.

Conclusions

In conclusion, the most important finding from the present study was that supplementation of the diet with UMMB made from cheaply but locally available non-conventional feed resources and binding agents can significantly improves the productivity of dairy cows without a compromise in the daily milk yield and compositions of lactating crossbred cows. The present findings also demonstrated that UMMB technology is a cost-effective approach to maximizing the utilization of locally available feed resources for better animal productivity during the dry season and may perhaps constitute an innovative feeding strategy for other species of livestock as well, where concentrate feeding is not a common practice, particularly in rearing of small ruminants. Nonetheless, it must be mentioned that there is a need for long-term studies on the response to these newly produced blocks on animals' productive and reproductive performance under smallholder condition that may yield information beyond the short-term responses observed in the present study. To confirm whether ideal ruminal fermentation can be met for efficient roughage utilization, these blocks shall be supported by trials that test the adequacy of rumen

NH3-N concentration and PH. In similar future research works the blocks shall also be investigated for their adequacy in meeting the mineral requirements of lactating crossbred cows.

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Study on silkworm bed cleaning frequency during larval growth period

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Abstract

Bed cleaning is an important silkworm rearing process to ensure the hygiene in the immediate vicinity of silkworms in order to protect from disease infection and to ensure them good feeding appetite. Hence, timely bed cleaning is essential to keep the worms healthy and productive. The treatments used for this study were one time bed cleaning frequency per instar, two times bed cleaning frequency per instar, three times bed cleaning frequency per instar, once bed cleaning frequency per day, twice bed cleaning frequency per day and no bed cleaning (control) to evaluate the effects of silkworm bed cleaning frequencies on silkworm races. Observations on larval mortality, larval period, single cocoon weight, shell weight, length of silk thread and silk ratio were carefully noted for each treatment and replications. Three replications were used for each treatment. Once bed cleaning frequency per day, twice bed cleaning frequency per day and three times bed cleaning frequency per instar significantly ($P < 0.05$) shortened the larval period of Vietnamese eri-silkworm races (23.7, 25 and 24.3 days), Indian eri silkworm races (29.8, 28.6 and 29.6 days), Kenyan bivoltine silkworm races (27.5, 30.6 and 31.5 days), Korean bivoltine silkworm races (24.7, 25.3, and 25.8 days) and Vietnamese multivoltine silkworm races (25.7, 25.8, and 25.8 days) respectively as compared to the untreated check which was 36.3 in Vietnamese eri, 55.4 days in Indian eri, 33.1 days in Kenyan bivoltine, 30.2 in Korean bivoltine and 30.3 in Vietnamese multivoltine silkworm races. Larval mortality was significantly higher for Vietnamese eri-silkworm races (8.25 & 15.58%), for Indian eri-silkworm races (5.01 & 11.66%), for Kenyan bivoltine silkworm races (12.2 & 30.06%), for Korean silkworm races (13.83 & 32.83%), for Vietnamese multivoltine silkworm races (0.33 & 45.5%) for the mature larval stages of 4^{th} and 5^{th} larval instars respectively in the untreated silkworm rearing beds. Among the tested treatments, three times bed cleaning frequency per instar, one time bed cleaning frequency per day and two times bed cleaning frequency per day significantly reduced larval mortality rate during the 4^{th} and 5^{th} larval instars of all silkworm races which was ranged between 0 to 0.33% for Vietnamese eri-silkworm races, 0.58 to 7.15% for Indian eri-silkworm races, 0.9 to 14.13% for Kenyan bivoltine silkworm races, 1 to 5.16 % for Korean silkworm races and 0.33 to 0.83% for Vietnamese multivoltine silkworm races. The young larval stages/instars (1^{st} to 3^{rd} instars) showed low larval mortality rate than mature larval stages (4^{th} and 5^{th} instars) in all silkworm races. Bed cleaning frequencies had no significant effect for 1^{st} instar for all silkworm races. All bed cleaning frequencies had no significant effect for Korean silkworm races and Vietnamese multivoltine silkworm races until the 3^{rd} instars. Hence, bed cleaning is not necessary during these stages in silk worm rearing practices for such races. Bed cleaning has showed a positive effect to reduce larval mortality rate for Vietnamese eri-silkworm races, Indian eri-silkworm races and Kenyan bivoltine silkworm races during 2^{nd} and 3^{rd} larval growth. Long spinning silk thread, robust silk cocoon and shell weight and higher percentage of silk ratio of silkworm races were registered from one time bed cleaning frequency per day and two times bed cleaning frequency per day.

Keywords: *bed cleaning frequency, silkworm races, larval period, larval mortality, cocoon weight, shell weight, silk thread, silk ratio*

Introduction

Sericulture is the process of obtaining the natural silk fiber through silk worm rearing, which can be practiced in varying agro-climatic conditions, and is suited to different production systems (Singh *et al*., 2002). Ethiopia is granted with diversified climate, vegetation and topography. This is also true for diversified options of sericulture industry which are adopted on different vegetation (for feeding of silk-worms) and different species of silkworms (Metaferia *et al*., 2007). FAO (1976) published that silk production is a highly profitable business enterprise that can produce a lucrative return from small portion of land where most of the land can be used for other food crops production. In Ethiopia, agricultural production is of a subsistence nature. Poverty and unemployment are the main challenges to the population, which therefore, requires additional on farm and off farm income generation technologies like raising of silkworms (silk production) (Metaferia *et al.*, 2007). As a result, silk production from eri silkworm (*Samia cynthia ricini*), a polyphagous insect, its primary feed plant (castor (*Ricinus communis* L.) (Raghavaiah 2003b), and mulberry silkworm (*Bombyx mori)*, a monophagous insect, feeds on only mulberry plant (*Morus* species) (Takano and Arai 1978) are commonly practiced in Ethiopia currently. Even though it is recently introduced in the country, promising results have been recorded in terms of generation of income and creation of employment opportunities (Metaferia *et al*., 2007). Silkworm rearing is an extensive month-long exercise starting from egg stage and terminating in adults laying eggs and dying their natural death. During this course, they pass through five larval instars (1st, 2nd, 3rd, 4th, and 5th instars) intervened by four moults, cocoon and pupal stage (Singh *et al.*, 2002). Silkworm rearing effectively means the culturing of five larval instars as other stages like egg, pupa and adults are non-feeding stages. In Ethiopia, whole life cycle spans through 46-56 days with 10-13 days of egg stage, 21-30 days of larval stage, 2-3 cocoon spinning days, 10-15 days as pupal duration and 3-5 days in adult stage (Abiy *et.al* unpublished). During larval growth stage bed cleaning is an important silkworm rearing process to ensure the hygiene in the immediate vicinity of silkworms in order to protect from disease infection and to ensure them good feeding appetite (Gogoi and Goswami 1998). The larvae should feed with appropriate quantity of leaves and feeding frequency based on the age/size of the larvae and their population in the bed (Ahmed *et.al* unpublished). Silkworms do not consume all the leaves that are supplied to them and invariably a part of the feed is left behind on the rearing bed. At the same time the larvae also defecate and their feces remaining on the rearing bed. If the residual leaves and the fecal matter are left on the rearing bed for some time, both start decomposing and fermenting there by quickly increasing the dampness of the bed. This adversely affects the larval physiology (Reddy and Swamy 1999). Therefore, it is essential to periodically remove these materials from the bed and keep it clean. The process of doing is known as bed cleaning.

Dried leaves, rejected leaf in the bed, silk worm’s excreta, exuviae, dead worms, diseased larvae all will increase the humidity, fermentation and temperature in the bed (Reddy and Swamy 1999). The authors further indicated that prevailing environmental conditions especially, temperature and relative humidity are vital in determining silkworm physiology as it is a cold-blooded organism. As soon as the larvae grow-up, the unconsumed leaves and litter increase in the rearing bed which ultimately cause changing atmosphere and favoring multiplication of pathogenic organisms such as protozoa, fungi, bacteria and viruses (Sannappa and Jayaramaiah 1999). Hence, bed cleaning should be done to remove fecal matter, dead worms and leaf remnants which would promote fungal, bacterial and viral infections (Sannappa and Jayaramaiah 1999). Diseases are the behavioral and physiological changes induced by pathogens in an organism (Hisao, 2001). If proper bed cleaning is not done in time it leads to various complications viz. ill health of larvae, disinterest of the larvae to feed due to unhygienic conditions, ultimately worms become weak and low in productivity (Hisao, 2001).Since they cause substantial financial loss to the silk producers, their prevention and control assumes utmost importance. Hence, timely bed cleaning is essential to keep the worms healthy and productive. The frequency of bed cleaning studies revealed that when larvae were not cleaned more number of dead larvae was observed compared to the treated beds (Zhang,*et al.,* 2002). They further revealed that regular bed cleaning every day minimizes the larval mortality (0.67%). It was higher in untreated beds (2.0-23.67%). This study indicated that the eri-silk worms allowed to clean once per day was recorded statistically significant highest cocoon weight (3.67 g) followed by twice per day (3.53-3.46 g). The worms on the untreated bed were recorded lowest cocoon weight (2.78-2.65 g) compared to other treatments used. The bed cleaning has influence on the shell weight and silk ratio of eri silkworms (Devaiah *et al*., 1985). According to their study the worms allowed for cleaning were recorded statistically significant maximum shell weight (0.35-0.33 g), and silk ratio (12.87 to 13.97%) compared to the un treated check, 0.30-0.27 g shell weight and 9.1 to 10.22% silk ratio. They further obtained that the length of the eri silk thread was maximum in worms allowed to clean which ranged from 6.1m to 5.82m and this was minimum (4.5 m) when worms were not received bed cleaning treatment. Sakthivel (2004) observed superior larval growth, development and higher cocoon production when eri silkworms were regularly cleaned according to their age, especially at late ages of 4th and 5th larval instars. According to them the progressive growth of silkworms was superior when properly fed and cleaned. The silkworm culture adaptation is being practiced in a large scale on the leaves of castor and mulberry with ideal feeding to administer nourishment to all the worms simultaneously and thereby to secure uniform growth and development of the worms (Neelu *et al*., 2000). They further mentioned that next to feeding, cleaning is an equally important factor. It is necessary for the health and progress of the worms. Considering all these factors the ideal cleaning intervals were studied. Sharma *et al*., (1996) also observed that silkworms at regular bed cleaning resulted in significantly higher larval weight, larval survival, cocoon weight, shell weight, shell ratio, pupal weight, and rate of pupation, silk productivity, fecundity and egg hatching with lower larval and pupal durations than those raised under no bed cleaning condition in farmers' practices. Bed cleaning is done after every moult for the young silkworms and every other day for the mature worms by some silk producers in others it is done once per day for all ages of silkworms as a blanket recommendation. Frequent cleaning is better but it involves more labor and ultimately silkworm rearing uneconomical. The present study was therefore conducted to determine stage wise bed cleaning frequency for each larval instars of the different silkworm races reared at Melkassa sericulture laboratory. The study also sought to examine the effect of bed cleaning frequency on larval mortality, larval period and yield components of the different silkworm races.

Materials and Methods

This experiment was carried out at Melkassa Agricultural Research Center, sericulture research laboratory between 2011 and 2013. Mulberry and eri-silkworm rearing were carried out on multivoltine and bivoltine silkworm breeds in the same laboratory as per appropriate recommendations (Dayashankar, 1982). The silkworm rearing equipments were cleaned, washed, sun dried and disinfected with 2% formalin solution at the rate of 800 ml per 10 m^2 areas before the commencement of rearing (Nataraju *et al*., 2005). The breeds were reared following shelf rearing techniques starting from brushing till cocoon spinning. Silkworms at larval stage were fed on mulberry and castor leaves four times a day with tender leaves until 3rd instar and mature leaves for 4th and 5th instars. Silkworms are fed four times in a day – morning (8-8:30 A.M.), mid-day (11:30-12:00 A.M.), after noon (2:00-2:30 P.M.) and evening (5-6 P.M.). Before bed cleaning, leaves spread on top of the feeding tray. Worms crawl up to feed. Then, the worms were shifted using the news paper to new beds and feeding is then resumed. The litter, leftover food and dead silkworms, were removed carefully and disposed off away from the rearing house. The grown up worms, after completing feeding during late fifth instar at their ripened stage (ready to spin silk) were picked and transferred on the mountages (equipment to provide support for cocoon formation) for spinning silk cocoons. Ripened silkworms were identified by their characteristics movement to the corners of the rearing beds, reduction in size and transparent yellow appearance. After six to eight days of spinning, cocoons were harvested from the mountages. Observations on larval duration, larval mortality rate and qualitative characters of the cocoon (fresh cocoon weight, cocoon shell weight, length of spinning thread and silk ratio) were recorded. Then, cocoon was boiled to make the serecin soft to dissolve. Silk filament was extracted out in which the coarser floss layer was removed. For the identification of causes of larval death, diseased larvae were examined. To grow fungal pathogens potato dextrose agar and for bacterial growth nutrient agar were applied. On the other hand, direct microscopic observation of the infected silkworm parts was used for the identification of silkworm diseases. Data such as number of infected silkworms versus total number of silkworms were recorded to determine the silkworm larval mortality rate.

Silkworm races used for this study were Vietnamese eri-silkworm races, Indian eri silkworm races, Kenyan bivoltine silkworm races, Korean bivoltine silkworm races, and Vietnamese multivoltine silkworm races. The treatments used for this study were one time bed cleaning frequency per instar, two times bed cleaning frequency per instar, three times bed cleaning frequency per instar, once bed cleaning frequency per day, twice bed cleaning frequency per day and no bed cleaning (control). Complete randomized design with three replications was used for each treatment and 200 silkworms were brushed in each replication and allowed to complete the larval period. Statistical analysis software (SAS) was used to analyze the data using analysis of variance (ANOVA) procedure. Least significant difference (LSD) was used for mean separation. Percentage proportions were calculated for larval mortality rate.

Results and Discussions

Effect of bed cleaning frequency on silkworm larval period:

Once bed cleaning frequency per day, twice bed cleaning frequency per day and three times bed cleaning frequency per instar significantly ($P < 0.05$) shortened the larval period of Vietnamese eri-silkworm races (23.7, 25 and 24.3 days), Indian eri silkworm races (29.8, 28.6, 29.6 days), Kenyan bivoltine silkworm races (27.5, 30.6 and 31.5 days), Korean bivoltine silkworm races (24.7, 25.3 and 25.8 days) and Vietnamese multivoltine silkworm races (25.7, 25.8 and 25.8 days) respectively as compared to the untreated check which was 36.3 in Vietnamese eri, 55.4 days in Indian eri, 33.1days in Kenyan bivoltine, 30.2 days in Korean bivoltine and 30.3 days in Vietnamese multivoltine silkworm races as indicated in figure 1.

Sachan and Bajpai (1973a) observed the larval duration of Eri silkworm on different host plants revealed that 22-27 days were required in good silkworm rearing condition to complete the larval development. The larval period in our study falls more or less within the same range as indicated by the authors. Significantly ($P < 0.05$) longer larval growth period was registered from the untreated check (55.5 days) as opposed to the shortest larval growth period from once bed cleaning frequency per day in Vietnamese eri silkworm races (23.7 days), in Kenyan bivoltine silkworm races (27.5 days), in Korean bivoltine silkworm races (24.7 days), in Vietnamese multivoltine silkworm races (25.7 days) (figure 1).

The entire larval period (1^{st} to 5^{th} larval stages) ranged from 23.7 days to 31.5 days feeding on castor and mulberry host plants (Reddy, 2008). The authors observed superior larval growth and higher cocoon production when eri silkworms were received ideal feeding, spacing and bed cleaning. Further, the larvae receiving once bed cleaning frequency per day during fifth instar had better growth (Joshi, 1987). According to this author the ideal bed cleaning is to administer good health to all the worms simultaneously and thereby to secure uniform growth and development of the worms. In this study the larval period to spin cocoons (the harvested row silk) was delayed (up to 46.5 days) when the bed cleaning frequency has prolonged to one time bed cleaning frequency per instar (figure 1). With no bed cleaning situation larval period was as high as 55.5 days and in treated silkworms it was as low as 23.7 days with a difference of about 22 days (figure 1). Shorter larval period indicate fast production period of row silk and longer larval period indicate prolonged production period of row silk which could influence the number of silk production times per year.

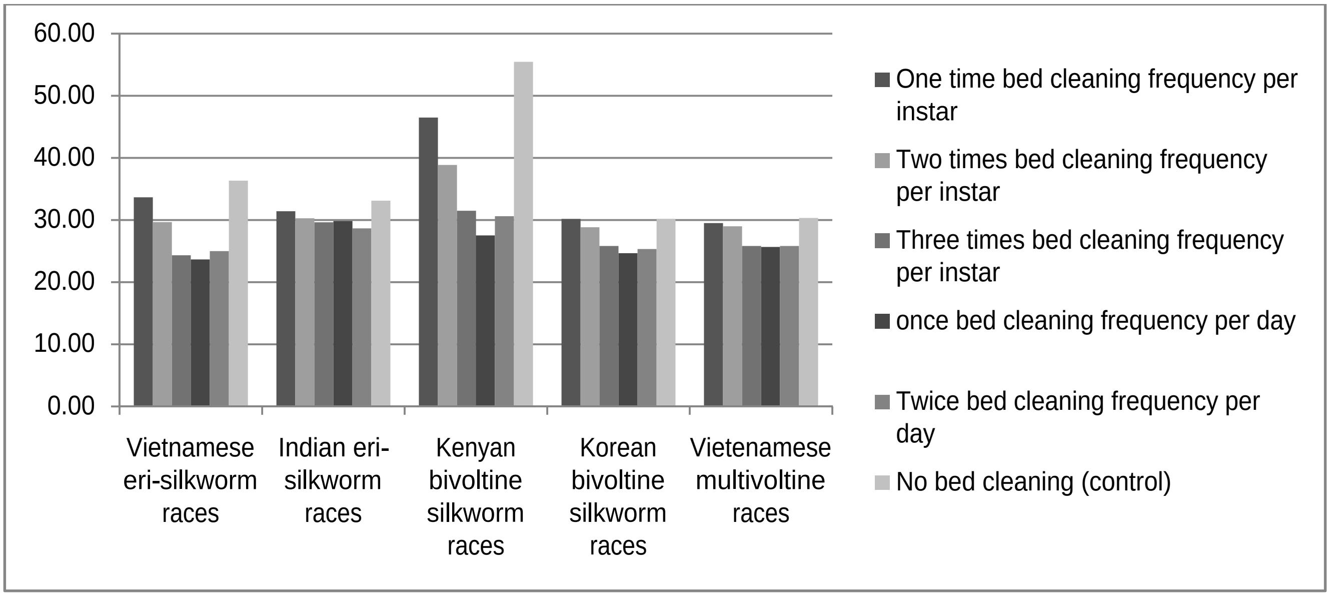

Figure 1: Effect of silkworm larvae bed cleaning frequency on larval period of different silkworm races

Effect of bed cleaning frequency on mortality of different larval instars and qualitative characters of the cocoon of silkworm races:

This study attempted to understand the effect of bed cleaning frequency on mortality of each larval instars (1st instar up to 5th instar larval stages) of silkworm races introduced from different countries. In this study qualitative characters of the silk cocoon **(**length of silk thread, silk cocoon weight, silk shell weight and silk ratio) were also evaluated to the different bed cleaning frequencies. Figures 2 to 6 summarizes the mean values of each larval instars mortality rate and Tables 1 to 5 summarizes qualitative characters of the silk cocoon after the 5th larval instar was treated to the different bed cleaning frequencies.

Vietenamese eri-silkworm races: Bed cleaning during the 1st instar larval growth has no significant effect on their mortality rate. A significant effect of bed cleaning was observed from 2nd instar up to 5th instar larval ages. The percentage of larval mortality ranged from 2.58% in the 2nd instar to 15.58% in the 5th instar in the control plots (figure 2). All levels of bed cleaning frequency except one time bed cleaning per instar was significantly superior in reducing larval mortality (below 0.41%) in 2nd and 3rd instar (figure 2). However, for these larval stages using two times bed cleaning frequency per instar among others could be economical to save time and labor. Significant variation was observed from three times bed cleaning per instar, once bed cleaning per day and twice bed cleaning frequencies per day in 4th and 5th instars which showed low number of larval death (below 0.33%).

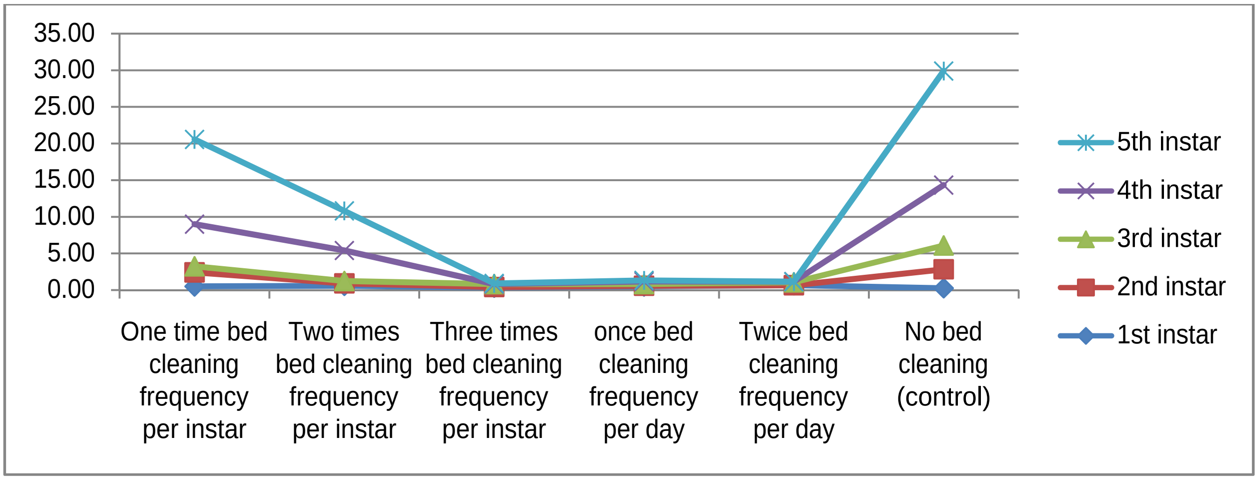

Figure 2. Effect of bed cleaning frequency on mortality of different larval instars of Vietnamese eri-silkworm races

Length of silk thread (5.77 m), silk cocoon weight (2.94 g), shell weight (0.28 g) and silk ratio (9.53%) were significantly ($P < 0.05$) lower when larval bed refuse and fecal matter of Vietnamese eri-silkworm larvae were not cleaned from rearing beds during their growth period than the tested bed cleaning frequencies (Table 1). Once and twice bed cleaning frequencies per day during the 5th instar were significantly ($P < 0.05$) resulted in higher length of silk thread (8.65 m & 8.51 m), silk cocoon weight (3.43 g & 3.44 g), shell weight (0.426 g & 0.436 g) and silk ratio (12.50% & 12.82%) as opposed to the other larval bed cleaning frequencies as indicated in Table 1.

Table 1. Effect of bed cleaning frequency on the qualitative characters of the cocoon of Vietnamese eri-silkworm races

Treatments	Length of silk thread (m)	Silk cocoon weight (gm)	Silk shell weight (gm)	silk ratio (%)
One time bed cleaning frequency per instar	6.76±0.15 b	3.11±0.02 b	0.306±0.003 d	9.78±0.07c
Two times bed cleaning frequency per instar	7.09±0.26 b	3.28±0.06 a	0.33±0.005 c	10.02±0.22 c
Three times bed cleaning frequency per instar	8.25±0.23 a	3.35±0.03 a	0.39±0.05 b	11.68±0.16 b
once bed cleaning frequency per day	8.65±0.16 a	3.43±0.05 a	0.426±0.003 a	12.5±0.23 a
Twice bed cleaning frequency per day	8.51±0.52 a	3.44±0.06 a	0.436±0.003 a	12.82±0.16 a
No bed cleaning (control)	5.77±0.08 c	2.94±0.04 c	0.28±0 e	9.53±0.17 c

Indian eri-silkworm races: There was no clear trend observed in the 1st larval instar interms of larval mortality rate through applying bed cleaning frequencies. Larval mortality was significantly higher in the untreated control during 2nd instar (2.46%), 3rd instar (6.4%), 4th instar (5.01%) and 5 th instar (11.66%) larval stages as opposed to all levels of cleaning frequencies (Figure 3). Significant results were achieved in reducing larval mortality rate from all levels of bed cleaning frequencies compared with the control (Figure 3). Two times bed cleaning per instar in 2nd larval age (0.66%), three times bed cleaning per instar (0.4%) and one time bed cleaning per day (0.28%) in 3rd larval age, once bed cleaning per day (0.61% and 0.58%) and twice bed cleaning per day (11.73% and 13%) in 4th and 5th larval stages respectively significantly reduced larval mortality rate (Figure 3). Though significant results were achieved in reducing larval mortality rate in all levels of bed cleaning frequencies, the result suggested that two times bed cleaning frequency per instar for 2nd , three times bed cleaning per instar for 3rd and once bed cleaning per day for 4th and 5th instars could be recommend to save time and labour.

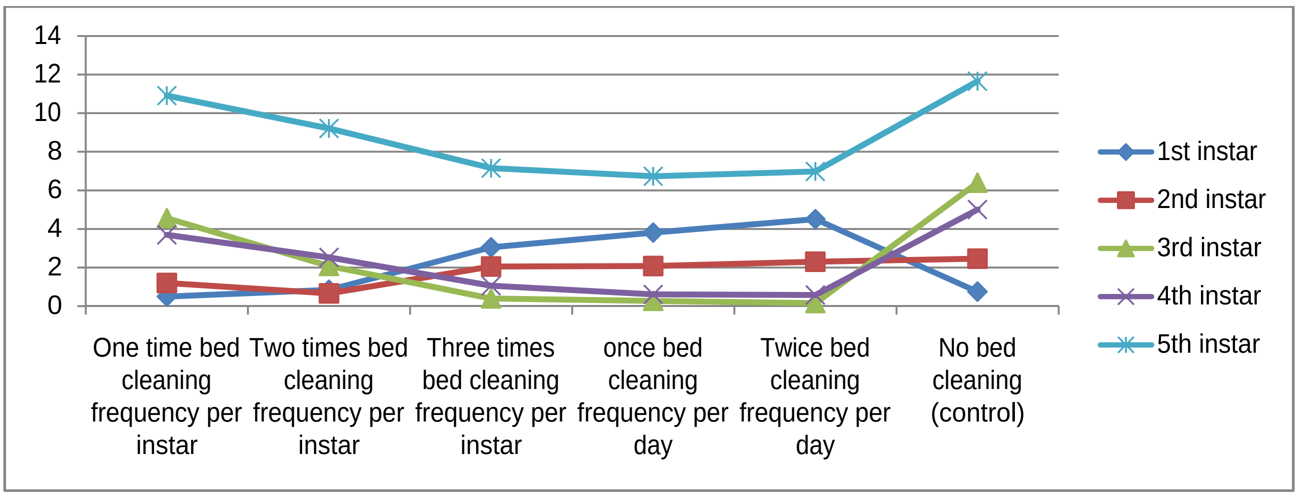

Figure 3. Effect of bed cleaning frequency on mortality of different larval instars of Indian eri- silkworm races

Length of silk thread (8.35 m & 8.28 m), and cocoon weight (3.36 g & 3.38 g), silk shell weight (0.4 g & 0.41 g) and silk ratio (11.95% to 12.21% were significantly ($P < 0.05$) increased when fecal matter of silkworm larvae and other left over's (dead worms and leaf remnants) cleaned in once bed cleaning frequency per day and twice bed cleaning frequency per day. In the control beds length of silk thread, silk cocoon weight, silk shell weight and silk ratio were greatly reduced to 5.9 m, 2.87 g, 0.246 g and 8.72% respectively (Table 2).

Table 2. Effect of bed cleaning frequency on the qualitative characters of the cocoon of Indian eri- silkworm races

Treatments	Length of silk thread (m)	Silk cocoon weight (gm)	Silk shell weight (gm)	Silk ratio (%)
One time bed cleaning frequency per instar	6.56±0.02c	3.05±0.06c	0.29±0.01d	9.61±0.15d
Two times bed cleaning frequency per instar	6.98±0.15b	3.12±0.05cb	0.313±0.003c	10.09±0.03c
Three times bed cleaning frequency per instar	8.3±0.10a	3.24±0.09ab	0.38±0.005b	11.73±0.19b
once bed cleaning frequency per day	8.35±0.07a	3.36±0.01a	0.4±0a	11.95±0.05ab
Twice bed cleaning frequency per day	8.28±0.01a	3.38±0.04a	0.41±0a	12.21±0.15a
No bed cleaning (control)	5.9±0.03d	2.87±0.02d	0.246±0.003e	8.72±0.16e

Kenyan bivoltine silkworm races: The highest larval mortality (3.6% to 30.06%) was registered when the larvae did not receive bed cleaning treatment in all level of larval instars except 1st instar (Figure 4). Two times bed cleaning per instar (1%) in 2nd larval stage, three times bed cleaning per instar (0.96%), one time bed cleaning per day (0.8%) and two times bed cleaning per day (0.53%) in 3rd larval stage, once bed cleaning per day (0.9% and 1.06%) and twice bed cleaning per day (11.73% and 13%) in 4th and 5th larval stages respectively significantly reduced larval mortality rate (Figure 4). Though significant results were achieved in reducing larval mortality rate in the above bed cleaning frequencies the result suggested that two times bed cleaning frequency per instar for 2nd , three times bed cleaning per instar for 3rd and once bed cleaning per day for 4th and 5th instars could be recommend to save time and labour.

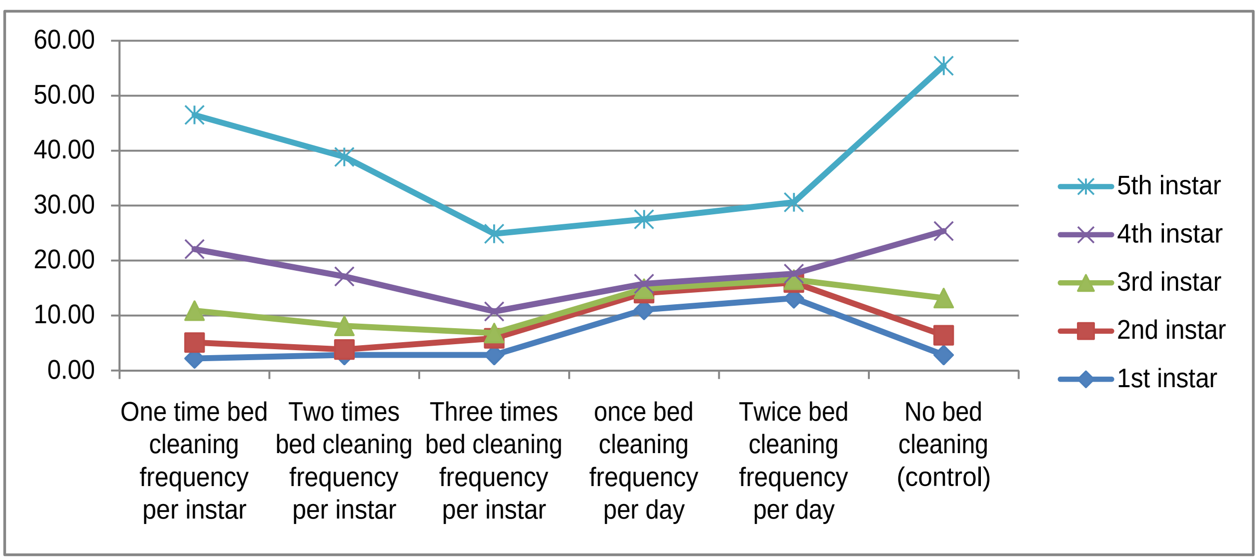

Figure 4. Effect of bed cleaning frequency on mortality of different larval instars of Kenyan bivoltine silkworm races

The untreated control significantly ($P < 0.05$) reduced the important yield components of silkworm larvae as indicated by the short length of single spinning thread (583 m), smaller silk cocoon weight (1.42 g), and smaller silk shell weight (0.263 g). Significantly ($P < 0.05$) higher percentage of silk ratio was registered from one time bed cleaning frequency per day (23%) and two times bed cleaning frequency per day (22.45%) as opposed to the lowest percentage of silk ratio from the check (18.49%). Significantly higher length of single spinning thread (915 m to 952 m), big silk cocoon weight (1.81g to 1.82 g) and big silk shell weight (0.41g to 0.42g) were obtained from the same treatments followed by three times cleaning frequency per instar larval developmental period for the same parameters (Table 3).

Table 3. Effect of bed cleaning frequency on the qualitative characters of the cocoon of Kenyan bivoltine silkworm races

Treatments	Length of silk thread (m)	Silk cocoon weight (gm)	Silk shell weight (gm)	Silk ratio (%)
One time bed cleaning frequency per instar	692.43±15.06c	1.62±0.02c	0.313±0.006c	19.25±0.10c
Two times bed cleaning frequency per instar	698.83±22.37c	1.64±0.01bc	0.316±0.003c	19.35±0.25c
Three times bed cleaning frequency per instar	854.56±19.62b	1.75±0.01ba	0.387±0.006b	22.11±0.40b
once bed cleaning frequency per day	915.18±15.38a	1.82±0.02a	0.410±0.005ba	22.45±0.08ba
Twice bed cleaning frequency per day	952.17±30.16a	1.81±0.01a	0.420±0.005a	23.00±0.35a
No bed cleaning (control)	583.01±5.44d	1.42±0.07d	0.263±0.013d	18.49±0.07d

Korean bivoltine silkworm races: bed cleaning has no significant effect in all level of treatments on larval mortality rate of Korean silkworm races until the 3rd larval instar. This indicates bed cleaning is not essential in 1st, 2nd and 3rd larval stages. Percentage larval mortality rate in these life stages was less than 0.83%. A significant effect among treatments was merely observed in 4th and 5th larval instars. A significant high mortality rate was recorded in the untreated control silkworm rearing beds during the above mentioned life stages. This was 13.83% and 32.83% respectively. Three times bed cleaning per instar (1.66%), one time bed cleaning per day (1.5%) and two times bed cleaning per day (1%) in 4th larval stage, once bed cleaning per day (0.83%) and twice bed cleaning per day (0.5%) in 5th larval stage caused a statistically low mortality rate (Figure 5).

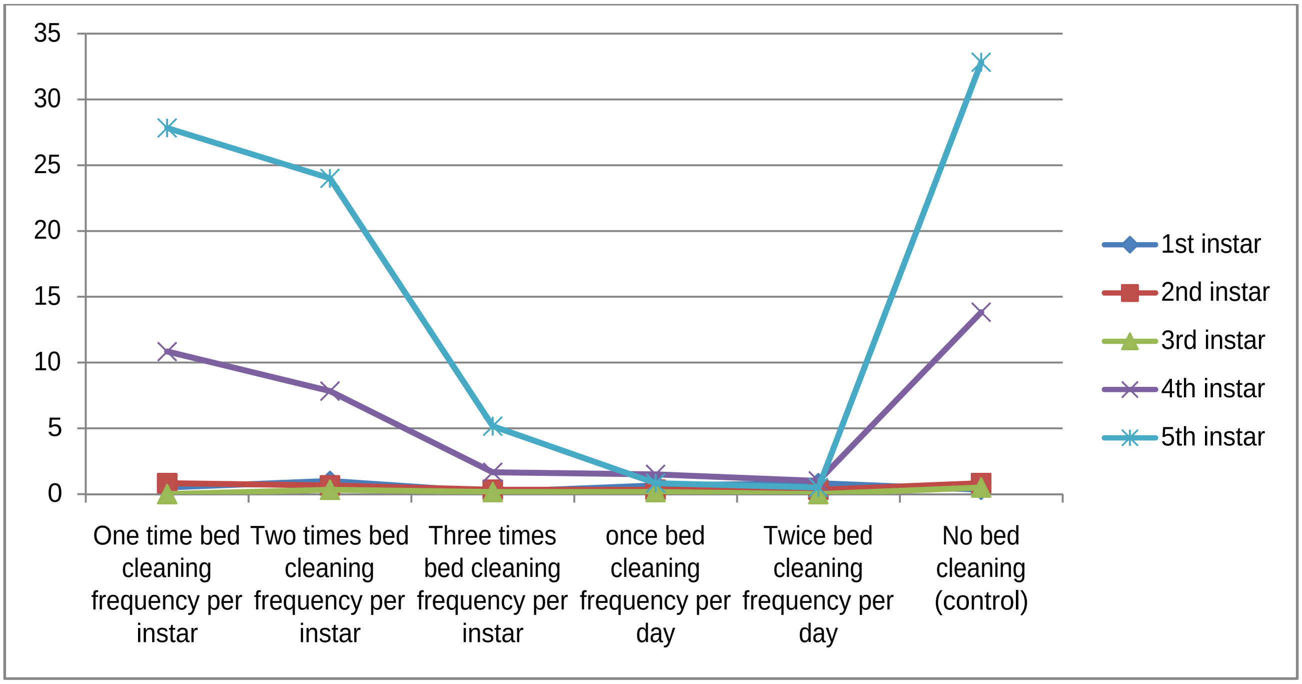

Figure 5. Effect of bed cleaning frequency on mortality of different larval instars of Korean bivoltine silkworm races

The length of spinning silk thread, silk Cocoon weight, silk Shell weight and Silk ratio produced from Korean bivoltine silkworm races were 611 m, 1.45 g, 0.27 g and 19% in the untreated check for the above order, while in the least effective cleaning frequency treatment (one time bed cleaning frequency per instar of larval growth period) this was 673 m, 1.65 g, 0.33 g, and 20.26% in the same order (Table 4). Once bed cleaning per day and twice bed cleaning per day were significantly ($P < 0.05$) superior than other treatments in improving length of spinning thread (950 m and 961 m), Cocoon weight (1.81 g and 1.77 g), Shell weight (0.42 and 0.40 g) and Silk ratio (23.03% and 22.31%) respectively (Table 4).

Table 4: Effect of bed cleaning frequency on the qualitative characters of the cocoon of Korean bivoltine silkworm races

Treatments	Length of silk thread (m)	Silk cocoon weight (gm)	Silk shell weight (gm)	Silk ratio (%)
One time bed cleaning frequency per instar	673.66±20.43dc	1.65±0.02b	0.337±b	20.26±b
Two times bed cleaning frequency per instar	719.00±22.23c	1.68±0.05ba	0.347±b	20.41±b
Three times bed cleaning frequency per instar	796.33±46.81b	1.80±0.04a	0.357±b	19.48±cb
once bed cleaning frequency per day	950.66±19.06a	1.81±0.05a	0.420±a	23.03±a
Twice bed cleaning frequency per day	961.00±17.61a	1.77±0.02ba	0.400±a	22.31±a
No bed cleaning (control)	611.66±13.86d	1.45±0.09c	0.277±c	19.00±c

Vietnamese multivoltine silkworm races: There was high larval mortality rate in some of the treated larvae than the untreated one in 1st instar larvae. This could be explained by the existence of other larval death causes such as mechanical damage of worms while feeding and bed cleaning practices. In the 2nd instar there was no much variability among the treatments with regard to larval mortality rate. A significant bed cleaning effect was not found in the 3rd and 4th instar larval growth by which larval mortality rate was not exceeded 0.83%. However mortality was drastically increased (45.5%) during the 5th larval stage in the untreated control. Mortality was reduced to 0.66% in three times bed cleaning per instar and once bed cleaning per day .No larval mortality bring into being from twice bed cleaning frequency per day treated rearing beds (Figure 6).

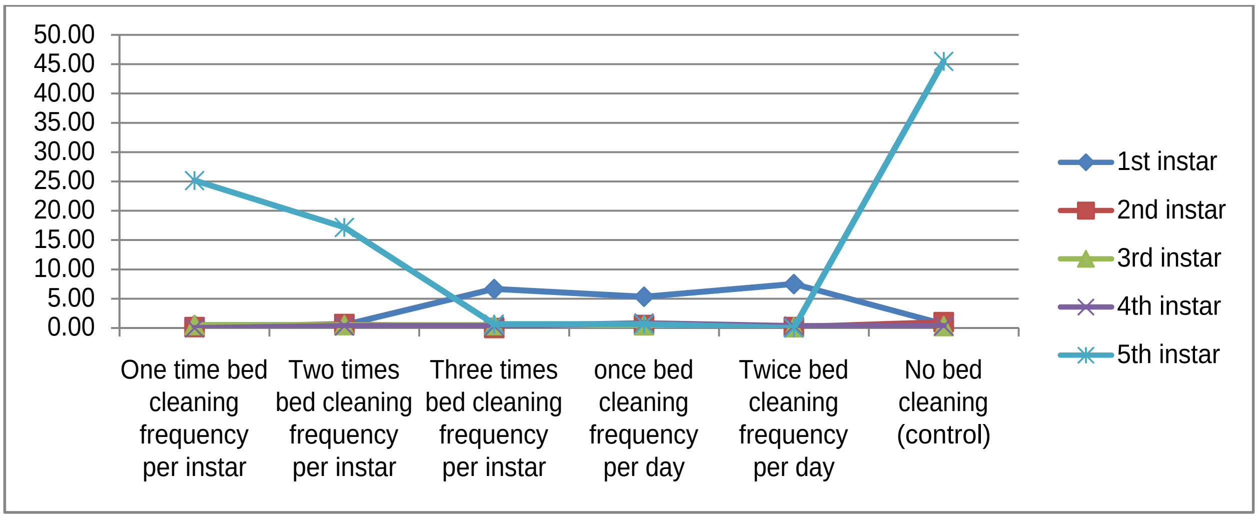

Figure 6. Effect of bed cleaning frequency on mortality of different larval instars of Vietnamese multivoltine silkworm races

Length of spinning silk thread (684 to 954 meters), Shell weight (0.303 to 0.377 gms) and Silk ratio (18.77 to 22.29%) (Table 5) were significantly ($P < 0.05$) higher in the treated silkworm larvae than the untreated one (666m, 0.27gms, and 18.59% respectively). Superior results were obtained from once bed cleaning frequency per day, twice bed cleaning frequency per day, and three times bed cleaning frequency per instar of silkworm larval growth period. Therefore we can use three times bed cleaning frequency per instar which is the least frequent bed cleaning interval among others to reduce larval mortality rate and to gain better silk cocoon yield.

Table 5: Effect of bed cleaning frequency on the qualitative characters of the cocoon of Vietnamese multivoltine silkworm races

Treatments	**Length of silk thread (m)**	**Silk cocoon weight (gm)ns**	**Silk shell weight (gm)**	**Silk ratio (%)**
One time bed cleaning frequency per instar	684.33±16.79c	1.59±0.07	0.303±0.020bc	19.00±0.34b
Two times bed cleaning frequency per instar	772.33±54.75bc	1.64±0.11	0.3100±0.017bc	18.77±0.19b
Three times bed cleaning frequency per instar	895.00±90.50ba	1.62±0.11	0.360±0.015ba	22.29±0.93a
once bed cleaning frequency per day	954.67±40.06a	1.72±0.01	0.377±0.003a	21.86±0.35a
Twice bed cleaning frequency per day	925.67±41.98a	1.65±0.06	0.367±0.013ba	22.13±0.26a
No bed cleaning (control)	666.33±11.83c	1.46±0.22	0.270±0.040c	18.59±0.46b

Sannappa and Jayaramaiah (1999) reported that as soon as the larvae grow-up, the unconsumed leaves and litter increase in the rearing bed which ultimately cause changing atmosphere and favoring multiplication of pathogenic organisms such as protozoa, fungi, bacteria and viruses. They further mentioned that due importance towards strict adherence to maintenance of hygienic conditions in and around the rearing house are a prerequisite for a successful cocoon harvest. So, ideal rearing condition such as bed spacing and bed cleaning should be done as per the different instars of larval stages and silkworm breeds. This study also confirmed there was variability in larval mortality rate among instars of different silkworm races in respective with various bed cleaning treatments. The results showed that bed cleaning caused significant reduction in larval mortality due to diseases against the control in all silkworm races. Silkworm diseases observed during our study were bacterial, fungal, and viral diseases. Rearing under better feeding and bed cleaning, ensuring pathogen free rearing conditions are some of the vital requirements for the growth of healthy worms that enables the silkworm tolerate adverse conditions. Periodic removal of bed refuse and fecal matter ensures good bed hygiene, prevention of diseases and good larval growth. The pilling of litter makes beds moist became favoring for multiplication of pathogenic microorganisms affects the health of worms and culture (Sannappa and Jayaramaiah 1999).

Devaiah *et al*., (1985) reported that feeding and cleaning are important silkworm management practices affecting the larval weight, silk gland weight, cocoon weight and shell weight considerably. Their observation on different bed cleaning frequencies indicated that once and twice bed cleaning treatments caused less mortality and greater effective rate of rearing compared to other treatments and these are statistically significant. Though these bed cleaning frequencies were consuming more time and labor they can resulting in less larval mortality and maximum effective rate of rearing. In our study the cocoon characters after the 5th instar was treated in once and twice bed cleaning treatments providing supportive evidence for good rearing condition, also statistically significant compared to other types of bed cleaning frequencies on many parameters. Bed cleaning experiment revealed that once bed cleaning per day, twice bed cleaning per day followed by three times bed cleaning per instar treatments were statistically superior in terms of minimum larval mortality, shorter larval period, longer silk thread, bigger cocoon weight, bigger silk shell weight and maximum percentage silk ratio depending on the successive larval stages of silkworm races (Tables 1 to 5). After successful silkworm rearing such as ideal bed cleaning, cocoon weight gain was recorded in previous findings. This difference in cocoon weight gain may be attributed to the difference in the bed cleaning treatments selected for the study and it may be inferred that treatments are a better performer than the control. Results from our study revealed that higher effective rate of rearing, higher cocoon weight; shell weight and silk ratio were obtained in the treatment against the control in all silkworm races. The findings of our study are in agreement with those of Joshi and Misra (1982); Hajarika *et al*., (2003). They found that higher effective rate of rearing, cocoon weight, shell weight and shell ratio were achieved in the bed cleaning treatments against the control. This was achieved by integration of not a single but a multitude of approaches viz. proper disinfection of the rearing room and appliances, use of bed disinfectant, bed spacing, bed cleaning and feeding as per recommendations. Prevention is better than Cure" is the correct approach and that should be adopted in integrated silkworm rearing management (Nataraju *et al*., 2005). This means that one should go about actively preventing diseases before it occurs, and it is only when preventive measures are in force that we can hope to effectively control the occurrence and spread of diseases. Patil *et al*., (2009) observed that eri silkworms receiving ideal bed cleaning treatment showed significantly higher larval weight (7.904 g), effective rate of rearing (90.0%), cocoon weight(3.683 g), shell weight (0.426 g), shell ratio (13.31%), pupal weight (3.256 g) with lower larval and pupal durations. Reddy *et al*., (1989b) recorded survival rate (95.67%), shell ratio (12.20%), and shorter developmental period (26.49 days) when eri silkworms were reared on ideal bed cleaning treatment. In Our study results indicating that the maximum shell weight (0.436 g), silk ratio (12.82%) and cocoon weight (3.44 g) have been obtained in eri silkworm shelf rearing method. Devaiah *et al*., (1985) reported that feeding, bed spacing and bed cleaning are important worm management practices affecting the larval weight, silk gland weight, cocoon weight and shell weight considerably. According to them maximum larval weight (7.6 g), cocoon weight (2.96 g) ,effective rate of rearing (90.0%), shell weight (0.44g) and silk ratio (14.9%) has been obtained in shelf method of rearing on castor.

Conclusion and Recommendation

This study confirmed that, once bed cleaning frequency per day, twice bed cleaning frequency per day and three times bed cleaning frequency per instar significantly shortened the larval period of Vietnamese eri-silkworm races, Indian eri silkworm races, Kenyan bivoltine silkworm races, Korean bivoltine silkworm races and Vietnamese multivoltine silkworm races. Larval mortality was significantly higher in all the tested silkworm races of the 4^{th} and 5^{th} larval instars in the control beds. Among the tested treatments, one time bed cleaning frequency per day, two times bed cleaning frequency per day and three times bed cleaning frequency per instar, significantly reduced larval mortality rate during the 4th and 5th larval instars of all silkworm races. The young larval stages (1st, 2nd, and 3rd instars) showed low larval mortality rate than the mature larval stages (4th and 5th larval instars). Bed cleaning frequencies had no significant effect for 1st larval instar in all silkworm races. All bed cleaning frequencies had no significant effect for Korean silkworm races and Vietnamese multivoltine silkworm races until the 3rd larval instars. Hence, bed cleaning is not necessary during these stages in silk worm rearing practices for such races. Bed cleaning has showed a positive effect to reduce larval mortality rate for Vietnamese eri-silkworm races, Indian eri-silkworm races and Kenyan bivoltine silkworm races during 2 nd and 3rd larval growth. The grown up worms, after completing feeding during late fifth instar at their ripened stage (ready to spin silk) are the once to be transferred on mountages for spinning silk cocoon. Bed cleaning is an important silkworm rearing process to ensure good hygiene and better feeding appetite especially during the 5th larval instar to obtain better cocoon yield components of silkworm races. In this regard, long spinning silk thread, robust silk cocoon and shell weight and higher percentage of silk ratio of silkworms were registered from one time bed cleaning frequency per day and two times bed cleaning frequency per day in the ripened stage of silkworm larvae for Vietnamese eri-silkworm races, Indian eri silkworm races, Kenyan bivoltine silkworm races, Korean bivoltine silkworm races. For Vietnamese multivoltine silkworm races better results for the same parameters were obtained from three times bed cleaning frequency per instar in addition to one time bed cleaning frequency per day and two times bed cleaning frequency per day. Though the above mentioned three treatments are superior in reducing larval mortality and increasing yield components of silkworm races, one time bed cleaning frequency per day and three times bed cleaning frequency per instar could be recommended to save time and labor for silk growers to ensure higher cocoon yield depending on the type of silkworm races . From this study it can be concluded that, if proper bed cleaning is not done in time it leads to various complications viz. ill health of larvae, disinterest of the larvae to feed due to unhygienic conditions, ultimately worms become weak and low in productivity. To this effect, stage wise bed cleaning frequency for each larval instar of the different silkworm races should be done to reduce larval mortality, to shortened larval period and to improve the yield components of the different silkworm races.

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Evaluation of Livestock Water for Macro and Micro Minerals in Selected Sites of the Central Highlands of Ethiopia

Running title: Evaluation of Livestock Water for Minerals in Highlands of Ethiopia
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Abstract

The study was undertaken to evaluate the status of PH and mineral concentration of livestock water. Water samples were collected from three locations of the central highlands of Ethiopia: Holetta, Akaki and Ambo. Samples were analyzed for macro minerals (Na, Ca, K, Mg) and micro minerals (Fe, Zn, Cu, Mn). The analysis was investogated by Atomic Absorption Spectrophotometer (AAS). There is variation in PH and mineral concentration of in water across and within a given location. As compared to Holetta and Ambo, livestock water in Akaki has the lowest PH (6.77) and the highest mineral concentration (32.22 ppm). Extreme minimum and maximum concentrations of minerals ranging from 0-160 ppm were recorded. Zero value for some elements implies they become below the detection limit. PH values ranging 3.93 to 9.95, 7.37 to 8.45 and 7.21to 8.01were recorded in Akaki, Ambo and Holetta respectively. The concentrations of macro minerals of water were found higher than the micro minerals. Regardless of the study location, the concentration of macro minerals were found in the order of calcium 26.43 ppm > sodium 24.68 ppm > potassium 19.84 ppm > magnesium 6.59 ppm. With regard to the micro minerals, they were found in the order of iron 31.93 ppm > manganese 10.26 ppm > zinc 0.29 ppm > copper 0.13 ppm.

The highest concentration of macro minerals recorded in Akaki, Ambo and Holetta were calcium (69.02 ppm), potassium (31.82 ppm) and sodium (9.35 ppm) respectively. The highest concentration of micro minerals recorded in Akaki, Ambo and Holetta were iron (89.95 ppm), manganese (9.20 ppm) and manganese (0.83 ppm) respectively.

In general, mineral content of livestock water have their own contribution to the daily mineral requirements of cattle. The concentration of calcium, magnesium, sodium, zinc and copper were found within the acceptable range. Whereas the concentrations of potassium in Akaki and Ambo (31.82 and 26.91 ppm), iron in Akaki, Ambo and Holetta (89.95, 5.5 and 0.33 ppm) and manganese in Akaki, Ambo and Holetta (20.76, 3.87 and 0.83 ppm) respectively were found beyond the acceptable level. Therefore, for an intervention to be implemented with mineral supplementation to livestock species, the mineral concentration of livestock water in certain location should be taken in to consideration. To overcome the excessive concentration of potassium, iron and manganese in water an adjustment targeting to the problematic element is required during feed formulation.

Keywords*: Cattle, Consumption, PH, quality, macro, micro*

Introduction

Water is a basic requirement for numerous functions of animal life. It is involved in regulation of body temperature and facilitates different physiological processes. It is the main transport medium for glucose, amino acids, mineral ions, water-soluble vitamins, and wastes (Jim and Mary, 2010; NRC, 1996). Water is the most important nutrient next to oxygen to sustain life (Beede, 2006). Water is predominately required for milk production which accounts 87% of the milk in dairy cows. A cow's body weight is composed of 56-81% water depending on stage of lactation (Beede, 2006). A cow faces fatal conditions when 20% of water weight is lost (Lejune et al, 2001). Consuming water is more important than feed because of water's vital importance to the animal's physiological functions (Matt and Sonja, 2012).

Both the quantity and quality of water are important to achieve optimal livestock performances (Jim and Mary, 2010). The hygienic and physic-chemical quality of drinking water plays a key role in ensuring an efficient animal productivity (Khan et al., 2012). Excessive chemicals in water can reduce animal production, impair fertility and cause losses of animals in some extreme cases (Khan et al., 2012). Contaminants in drinking water can leave residues in animal products, i.e. meat, milk and eggs, which adversely affect product sales and transfer health risks to humans (Lili, 2009 In: Khan et al., 2012). Poor quality water brings abnormal taste and/or odor, leading to reduced water intake, feed intake and health of the animal which consequently affect growth, reproductive and productive performance (Dave, 2008). The odor or taste of water is attributed to anti-quality elements which affects the normal metabolic, physiological functions and health status of the animal (Beede, 2006; Tayler and Foster, 2012). As with the feed, water used for livestock drinking should meet the nutritional needs of the animal. Minerals found in water provide nutritional benefits when present in optimum concentrations. Very minute (micrograms or milligrams) quantities of minerals are required for effective physiological process (Dawd, 2010). Minerals are classified in to macro and micro minerals (Faye et al., 2011). Major or macro minerals are the six dietary minerals living organism needs in largest amounts. They're necessary for many processes such as fluid balance, maintenance of bones and teeth, muscle contractions and nervous system function. Major minerals include calcium (Ca),potassium (K), sodium (Na) magnesium (Mg) and phosphorous (P). Trace minerals are all essential for good health, but a living organism needs in a very small amount. They are important for immune system function, energy, metabolism and antioxidant protection. Trace minerals include chromium, copper, fluoride, iodine, iron, manganese, molbedinium, selenium, zinc (Faye et al., 2011). Minerals contribute to the bone structure (Ca, P, Mg), to the electrolyte balance (Na, K) to the protein structure (Fe and Cu), nervous and muscle activities (Ca and K) or to the enzyme activities (Zn Se). Minerals are known to be essential for normal growth (Li-Qiang et al., 2009; Tekleyohannes Berhanu and Agrawal, 2003). They are used as co-factors in many enzymes and play an important role in many physiological functions. Lack of minerals causes disturbances and pathological conditions (Enb et al., 2009). Mineral deficiency could result to deficiency disease and their excess in the diet could provoke toxicity. Mineral imbalance could affect bone metabolism, provoke growth disturbances, loss of appetite, reproductive failure, immune-depression and abnormal feeding behavior.

Since water is one of the reservoirs of minerals, there is an interest to study its minerals status (Patra et al, 2008). Water provides variable amounts of minerals depending its location (Li-Qiang et al., 2009. There is a threshold level of minerals above which may cause nutritional and (or) health problems (Breede, 2006; Federal Ministry of health, 2004). In between there is a set of intakes that represent the acceptable range of oral intakes (AROI), at which no adverse effects occur. Water should be periodically sampled for quality and potential contaminants (Matt and Sonja 2012). The parameters commonly used to evaluate water quality include pH, salinity, alkalinity, sulphate, nitrate, hardness, toxic elements, contaminations with pesticides and fertilizer products. The pH of water can affect taste of water and efficiency of chlorination (Jane, 2009). Highly acidic pH leads to acidosis and reduced feed intake and highly alkaline water causes digestive upsets, diarrhea, reduced water intake, lower feed intake and lower feed conversion efficiency (Jane, 2009). Ions of Magnesium, Calcium, Sodium, Chloride, Carbonates, bicarbonates, sulphates, nitrates, chlorides, phosphates and fluorides, are associated with salinity of water and they may cause toxic effects when they are found beyond the acceptable level (Marx, 2003). For example deficiency of calcium and phosphorus leads to problem of poor reproductive performance such as inter-calving interval and the lower content and quality of fat in milk (Rekhis et al., 2002). Iron concentrations in drinking water greater than 0.3 ppm are considered a concern for dairy cattle health and performance. Water caused by high calcium levels can influence the incidence of milk fever in dairy herd. Higher levels of calcium, sodium and magnesium can reduce palatability of water. Higher levels of nitrates, fluorine, salts of heavy metals such as copper, zinc and manganese in water are toxic. The presence of sodium bicarbonate in drinking water can cause sheep to bloat, particularly if the animals are under stress and not accustomed to the water (Salinity management handbook, 2013).

Some research activities have been undertaken on mineral status of feed stuffs (Lemma Gizachew and Smit, 2005). However, information is lucking on mineral composition of water used for livestock drinking. Therefore, there is a need to determine the level and concentration of macro and micro minerals elements in livestock water.

Objectives

- To determine the PH status of livestock water across different locations
- To assess the concentration of macro and micro minerals in livestock water and its contribution to the daily requirements of cattle

- To compare the concentration of macro and micro minerals against the Official Standard of acceptable limits

Materials and methods

Description of the study locations

The study was carried out in three locations of the central highlands of Ethiopia: Akaki, Holetta and Ambo.

Akaki: it is located in central Ethiopia along theWestern margin of the Main Ethiopian Rift. The catchment is geographically bounded between 8°46´–9°14´N and 38°34´–39°04´E (Molla and Stefan, 2006).

Holetta: it is located at 38° 30`E, 9° 3`N and 45 km west of Addis Ababa and lies at an elevation of 2400 m.a.s.l. The annual rainfall is 1066 mm with bimodal distribution, over 70% of which occurs during the main rainy season (June to September) and 30% during the small rainy season (February to April). The average annual minimum and maximum temperatures were 6° and 22°C respectively. The area is also characterized by occasional frost that occurs in the months of October to December, where temperatures below zero for few days during these months (Fekede et al., 2004).

Ambo: it is located in central Ethiopia of the Western Shewa Zone of the Oromia Regional state. It is situated 115 km West of Addis Ababa. The area is found at a longitude of 370 32’ to 380 3’ E, and latitude of 80 47 ’ to 90 20’ N and the altitude ranges from 1900 -2275 meters above sea level. The climatic condition of the area is 23% highland, 60% mid altitude, and 17% lowland. It has an annual rainfall and temperature ranging from 800-1000 mm and 20-29 0 C respectively. The rainfall is bi-modal with short rainy season from February to May and long rainy season from June to September (AARDB, 2006 In: Indrias et al, 2010). Agriculture is the main occupation of the population. Agricultural activities are mainly mixed type with cattle rearing and crop production under taken side by side. Ambo is known for its mineral water, which is bottled outside of town which is reportedly the most popular brand in Ethiopia.

Sampling methods and laboratory analysis

Collection of water samples was carried out at field conditions where different livestock species practically drink water within the study location of Akaki, Ambo and Holetta. Ten water samples were collected from each study locations including. Plastic sample bottles with a capacity of 0.5 lt was used for water container. To make the containers clean, they were rinsed with distilled water, labeled according to the pre-designed study locations. Water samples were taken from small water bodies manly surface water usually used for livestock drinking. The sample bottles were filled to the top and capped tightly. The bottles were wiped to make them dry. Before taking to the laboratory , the samples were investigated for physical appearances like color, turbidity and odor. Then they were measured for PH and delivered to Debrezeit soil and plant laboratory for analysis. Investigation of water was carried out for macro minerals including Na, K, Ca, Mg, and micro minerals including Cu, Zn, Fe, and Mn based on the standard procedures of Atomic Absorption Spectrophotometer (AAS). The PH of water was measured by PH/ion-meter, WTW, Inolab (Germany).

Experimental design

The experimental design was randomized completely block design (RCBD). The study locations including Akaki, Holetta and Ambo were considered as block.

The statistical model was:

$Y_{ijk} = \mu + Mi + Lj + (M*L)k + eijk$ Where,

Y_{ijk} = the response variable

μ = the overall mean

Mi = effect of i^{th} mineral element

Lj = effect of j^{th} study location

(M*L)k = interaction effects of i^{th} mineral element and j^{th} study location

eijk = the random error

Statistical analysis

There is a wide range of variation among the concentration of mineral elements which varies from 0 ppm – 262 ppm. Due to this, the standard deviation (root MSE) of some elements was found greater than the respective mean. When the data was tested for assumptions of normality, it does not fulfill curve of normal distribution. To fulfill the normal curve, we are forced to transform the data using the square root transformation and we have got the transformed data. Then both the transformed and untransformed data was subjected to Analysis of variance and the General Linear Model Procedures (GLM) was used to perform the analysis. Ls-means of both the transformed and untransformed data are considered and the standard error is taken from the transformed data. Least square means of the transformed data is put in parenthesis.

Mineral intake from water and its contribution to mineral requirement

For the estimation of major and minor minerals, maintenance requirement of minerals was considered as focal point of calculation. To perform this different research results was used as references. To estimate the maintenance requirement of calcium for non-lactating mature cattle, the absorbed calcium required is 0.0154 g/kg body weight (Hansard et al., 1957 In: NRC 2001). This requirement should be added to the total inevitable losses in the form of urine and faces that is 0.015 grams/kg body weight per day (Gueguen et al. 1989, In: NRC 2001). To estimate the maintenance requirement of sodium, the absorbed sodium for lactating cows was set at 0.038 g/kg of body weight per day. This requirement needs to be added to the total inevitable losses in the form of urine and faces that is 0.015 grams/kg body weight per day (NRC 2001). In addition, at environmental temperatures between 25 and 30° C, an additional 0.10 g of sodium per 100 kg body weight is lost in the form of sweat which is considered to be part of maintenance (Agricultural Research Council, 1980). The maintenance requirement for absorbed potassium of lactating cows was set as 0.038 g/kg body weight (endogenous urinary loss) plus 6.1 g/kg of dietary dry matter (endogenous fecal loss) (Sanchez et al., 1994a,b In: NRC 2001). At environmental temperatures between 25°C and 30° C, an additional 0.04 g of potassium/100 kg body weight was considered part of maintenance requirement. The maintenance requirement for absorbed magnesium requirement is 0.33 g/day (Lyford and Huber, 1988). On top of rhis, the fecal loss of endogenous Mg is 3 mg/kg body weight for adult cattle and heifers in 100 kg BW (NRC, 1996, In NRC 2001). Obligate urinary loss of magnesium is negligible. The daily copper requirement for 300kg body weight is 72mg/day (NRC, 2000, In: NRC 2001). The iron requirement of mature lactating cow is 24 mg /kg DM (Henry and Miller, 1995, In NRC, 2001). The daily Mg requirement of cattle is 40 mg/kg DM feed. (NRC1989b, In: NRC 2001). The maintenance requirement of zinc is the sum total of the absorbed zinc requirement of 0.045 plus the daily endogenous fecal loss which is approximately 0.033 mg zinc/kg body weight and the the obligate urinary loss of zinc is estimated as 0.012 mg zinc/kg body weight (Hansard et al., 1968, In NRC, 2001).

Results and Discussions

PH values of livestock water across sampling sub location are presented in Table 1. Both low and higher PH values within a range of 3.93-9.95 were recorded in Akaki. Whereas PH of 7.37-8.45 and 7.21-8.01 within the acceptable range of 6.5–8.5 (Peterson, 1999) were recorded in Ambo and Holetta respectively. Majority of the sampling sites have PH within in the acceptable range. However, some sub-locations in Akaki including Legedukem 1 (PH=9.95) and Legedukem 2 (PH=9.87) have PH value of greater than the acceptable range. In the same location, lower PH values were also recorded in sub study sites called Tach Dengora 1, Tach Dengora 2, Lay Dengora 1, Lay Dengora 2 which is 3.93, 4.1, 5.28 and 4.04 respectively (table 1). As compared to Holetta and Ambo, the PH of water across Akaki sampling sites has a wide range of variation. Water pH is used to describe the acidity or alkalinity and the concentration of hydrogen ion in water determines the PH level. Most water falls within an acceptable range of 6.5 to 8.5. Water PH lower than 5.5 poses to problem of acidosis and reduced feed intake in cattle (Jane, 2009). It was also suggested that PH value greater than 9.0 may result in problems related to chronic or mild alkalosis (Adams and Sharpe, 1995). Moreover water PH is an important factor in determining the effectiveness of various water treatments. For example, chlorination efficiency is reduced at a higher water PH. A low PH may cause precipitation of some antibacterial agents delivered through the water system (MOA, 1999). Water PH as a measure of water quality could cause low water intake. Anti-quality factors (constituents in excess or unwanted compounds) present in water may affect PH value and consequently water intake, or normal metabolic or physiological functions of animals (Beed, 2006).

Table 1. PH range of livestock water across sampling sites

Akaki	Sampling sites in Akaki										
	Lege Dukem 1	Tulu Dumtu 1	Tach Dengora1	Lay Dengora 1	Fanta Wenz 1	Tulu Dumtu 2	Tach Dengora 2	Lay Dengora 2	Fanta Wenz 2	Lege Dukem 2	PH range
PH	9.95	7.34	3.93	5.28	8.08	7.38	4.1	4.04	7.43	9.87	3.93-9.95
Holetta	Sampling sites in Holetta										
	Kui 1	Kui 2	Weservey 1	Weservey 2	Holetta Wenz 1	Ureni 1	Ureni 2	Korejela 1	Korejela 2	Holetta Wenz 2	
PH	7.41	7.21	7.46	8.01	7.39	7.31	7.40	7.48	7.54	7.37	7.21-8.01
Ambo	Sampling sites in Ambo										
	Boji Wenz 1	Boji Wenz 2	Huluka 1	Huluka 2	Umuga 1	Umuga 2	Cholu 1	Cholu 2	Chancho 1	Chancho 2	
PH	7.68	7.67	8.45	7.82	7.40	7.96	7.91	7.72	7.48	7.37	7.37-8.45

The PH value and mineral concentration of livestock water is presented in Table 2. The PH of livestock water in Akaki (6.77 ± 0.15) differs significantly ($P < 0.01$) and is lower when it is compared with PH of water in Ambo (7.74 ± 0.15) and Holetta (7.45 ± 0.15). However, there is no significance ($P > 0.01$) difference between PH of water in Ambo and Holetta. There is highly significance ($p<0.01$) difference in concentration of minerals across study locations. Regardless of the mineral type, the concentration of minerals in water in Akaki (32.22 ± 3.45) is significantly ($p<0.05$) higher than that of in Ambo (9.82 ± 3.45) and in Welmera (3.02 ± 3.45). The interaction effect between mineral elements and study locations is also highly significant ($p<0.01$). The results also indicated that PH values of livestock water were almost negatively correlated with the corresponding concentration of minerals ($r = ^{-}0.40472$, $P < 0.0001$).

The PH level is determined by the hydrogen ion concentration. A pH value of 7 indicates "neutral" water. Values less than 7 are increasingly acidic and values greater than 7 are increasingly alkaline. Most water falls within an acceptable range of 6.5 to 8.5. If the pH is lower than 5.5, acidosis and reduced feed intake may occur in cattle. A low water pH is unlikely to have any direct effect on swine because of the already acidic conditions of the stomach. Water pH is an important factor in determining the effectiveness of various water treatments. Chlorination efficiency is reduced at a high pH. A low pH may cause precipitation of some antibacterial agents delivered through the water system. For example, sulphonamides are a particular concern as precipitated medication may leak back into the water after treatment has ended, contributing to potential sulpha residues in carcasses (Karen ,1999).

Few studies have linked water pH with any livestock health or performance issues. Adams and Sharpe (1995) suggested that water pH should fall between 5.1 and 9.0 based on experiences with dairy herds in Pennsylvania. They suggested that acidic water with a pH less than 5.1 may increase problems related to chronic or mild acidosis while water with a pH over 9.0 may result in problems related to chronic or mild alkalosis. Other authors have recommended a more strict pH range between 6.0 and 8.5 largely based on field observations rather than controlled studies. It was suggested that water supplies with a pH below 6.0 or above 8.5 should be further evaluated where unexplained herd health or performance issues occur. The PH of livestock water in the present study was found in the recommended range which is between 6.8 and 7.5.

Table 2. PH and mineral concentration of livestock water across study locations (LS-means ± SE)

Location	PH (unit)	Concentration of minerals (ppm)	
Akaki	6.77 ± 0.15^{a}	32.22 ± 0.24^{a}	$(4.01)^{a}$
Ambo	7.74 ± 0.15^{b}	9.82 ± 0.24^{b}	$(2.10)^{b}$
Holetta	7.45 ± 0.15^{b}	3.02 ± 0.24^{bc}	$(1.28\ )^{c}$

LS-means labeled with different superscripts between rows differ significantly.
Figures indicated in parenthesis are the transformed Ls-means.

Based on the assumption that camel drink about 31.3 L of water per day in hot dry season (Pallas 1986), (Zinash) the results of the chemical analysis of the waters were used to estimate the daily mineral intake of the animals from the different sources. Estimation assumed an average body weight of 410 kg per animal (1.6 TLU) and a daily feed intake of 9 kg DM (ILRI 2002). These figures were used in the calculation of the daily requirement of camel for the different minerals analyzed. In this respect, the following recommendation of the expected mineral composition per kg dry weight of forage was taken into consideration: 0.3% (Ca), 0.2% (Mg), 0.06-0.18% (Na), 0.6-0.8% (K), 0.25% (P), 40 mg kg-1 (Mn), 50 mg kg-1 (Fe), 30 mg kg-1(Zn) and 10 mg kg-1 (Cu) (McDowell and Arthington 2005).

Minerals required in gram quantities are referred to as macro minerals and they include calcium, phosphorus, sodium, chlorine, potassium, magnesium, and sulfur. macro minerals are important structural components of bone and other tissues and serve as important constituents of body fluids. They play vital roles in the maintenance of acid-base balance, osmotic pressure, membrane electric potential and nervous transmission. Minerals required in milligram or microgram amounts are referred to as the trace minerals. They include cobalt, copper, iodine, iron, manganese, molybdenum, selenium, zinc, and perhaps chromium and fluorine. The trace minerals are present in body tissues in very low concentrations and often serve as components of metalloenzymes and enzyme cofactors, or as components of hormones of the endocrine system (NRC, 2011).

The average concentration of macro and micro mineral elements regardless of the study locations is indicated in table 3. In all the study locations, the concentrations of macro minerals of livestock water were found higher than the micro minerals. The concentration of macro minerals in livestock water were found in the order of calcium (26.43 ppm) > sodium (24.68 ppm) > potassium (19.84 ppm) > magnesium (6.59 ppm). The results also indicated that there is no significance difference ($p>0.05$) among the concentration of calcium, sodium and potassium in livestock water. However, there is significance difference ($p<0.001$) between the concentration of magnesium as compared to the above elements. The concentration micro minerals in livestock water was found in the order of iron (31.93 ppm) > manganese (10.26 ppm) > zinc (0.29 ppm) > copper (0.13 ppm). There is no significance difference ($p>0.05$) between the concentration of copper (0.13 ± 0.40) and zinc (0.29 ± 0.40). Similarly there is no significance difference ($p>0.05$) between the concentration of iron (31.93 ± 0.40) and manganese (10.26 ± 0.40). However, there is significance difference ($p<0.001$) between the concentration of copper (0.13 ± 0.40) in comparison to iron (31.93 ± 0.40) and manganese (10.26 ± 0.40). Similarly, there is significance difference ($p<0.001$) between the concentration of zinc (0.29 ± 0.40) in comparison to iron (31.93 ± 0.40) and manganese (10.26 ± 0.40).

Table 3. Concentration of macro and micro mineral elements in livestock water (LS-means ± SE)

Mineral element	Concentration (ppm)	
Macro mineral		
Na	24.68 ± 0.40[a]	(4.70)[a]
Ca	26.43 ± 0.40[a]	(3.67)[a]
K	19.84 ± 0.40[a]	(3.58)[af]
Mg	6.59 ± 0.40[cba]	(2.37)[c]
Micro minerals		
Cu	0.13 ± 0.40[b]	(0.36)[b]
Zn	0.29 ± 0.40[eb]	(0.50)[e]
Fe	31.93 ± 0.40[a]	(2.75)[fcd]
Mn	10.26 ± 0.40[da]	(1.77)[dc]

LS-means labeled with different superscripts among rows are significantly different.
Figures indicated in parenthesis are the transformed Ls-means.

The concentration of macro and micro minerals in livestock water across different study locations is indicated in table 4. Among the macro minerals, highest concentration of calcium (69.02 ± 0.70 ppm), potassium (31.82 ± 0.70 ppm) and sodium (9.35 ± 0.70 ppm) were found in Akaki, Ambo and Holetta respectively. The lowest concentration of magnesium (9.77 ± 0.70 and, 3.87 ± 0.70) was measured in Akaki and Ambo respectively. Potassium has the lowest concentration in Holetta (0.79 ± 0.70 ppm). For the micro minerals, highest concentration of iron in Akaki (89.95 ± 0.70 ppm), manganese in Ambo (9.20 ± 0.70 ppm) and manganese in Holetta (0.83± 0.70 ppm). Copper was the element found in lowest concentration in Akaki (0.10 ± 0.70), Ambo (0.13 ± 0.70) and Holetta (0.16 ± 0.70).

Sodium in water is rarely problematic for dairy cattle but sodium concentrations should be included in the ration formulation if levels are below 20 mg/L (ppm). The sodium levels in the present study were 40.78 ppm, 23.93 ppm and 9.35 ppm in Akaki, Ambo and Holetta respectively. Since the sodium level in livestock water in Akaki and Ambo are found beyond the recommended level, there is no need to include sodium in the feed formulation. Whereas, the concentration of sodium in livestock water in Holetta was found below the recommended level, there is a need to include sodium in the ration formulation.

Iron and manganese are very common pollutants that can occur naturally in groundwater or from nearby mining activities. Both cause severe staining and a metallic taste to water resulting in reduced water intake and reduced milk production. Iron levels above 0.3 mg/L and manganese concentrations exceeding 0.05 mg/L are sufficient to cause unpleasant tastes in water that may cause reduced water intake and milk production. In the present study, the concentration of iron in Akaki, Ambo and Holetta were 89.95 ppm, 5.5 ppm and 0.33 ppm respectively. Here the concentration of iron especially in Akaki and Ambo are beyond the recommended level. Here attention is required no to supplement feeds rich in iron to minimize the cumulative effect of excessive iron coming from water and feed. The concentration of manganese in Akaki, Ambo and Holetta were 20.76 ppm, 9.20 ppm and 0.83 ppm respectively. In all the study locations, manganese was found in higher concentration. Here care is required not to supplement feeds rich in manganese so as to minimize the cumulative effect of excessive iron coming from water and feed.

Copper usually occurs in water from corrosion of metal plumbing components. It may also be elevated in mining areas or from treatment of ponds with copper sulfate algaecides. Copper levels above 1.0 mg/L may cause a metallic taste resulting in reduced water intake and milk production. High copper concentrations may also cause liver damage. The concentration of copper in livestock water in the present study was 0.1 ppm, 0.13 ppm and 0.16 ppm in Akaki, Ambo and Holetta respectively. Here the indicated copper concentration is found below the recommended level. It is therefore required to include copper in the feed formulation to optimize the cupper requirement of different livestock species.

Table 4. Concentration (ppm) of macro and micro minerals in livestock water across locations (Ls-means ± SE)

Mineral element	Akaki	Ambo	Holetta
Macro mineral			
Sodium	40.78 ± 0.70a (6.37)a	23.93 ± 0.70ac (4.69)a	9.35 ± 0.70c (3.04)c
Calcium	69.02 ± 0.70a (6.92)a	3.94 ± 0.70bc (1.63)bc	6.35 ± 0.70c (2.47)c
Potassium	26.91 ± 0.70ac (5.01)a	31.82 ± 0.70c (4.99)a	0.79 ± 0.70ab (0.73)c
Magnesium	9.77 ± 0.70a (2.94)a	3.87 ± 0.70a (1.70)a	6.12 ± 0.70a (2.47)a
Micro mineral			
Copper	0.10 ± 0.70a (0.31)a	0.13 ± 0.70a (0.36)a	0.16 ± 0.70a (0.39)a
Zinc	0.46 ± 0.70a (0.59)a	0.20 ± 0.70a (0.44)a	0.22 ± 0.70a (0.47)a
Iron	89.95 ± 0.70a (6.23)a	5.5 ± 0.70bc (1.62)bc	0.33 ± 0.70c (0.40)c
Manganese	20.76 ± 0.70a (3.67)a	9.20 ± 0.70a (1.36)bc	0.83 ± 0.70a (0.29)c

LS-means labeled with different superscripts among rows are significantly different. Values indicated in parenthesis are the transformed Ls-means.

The mean PH value and mineral concentration of livestock water across study locations is presented in fig 1. The PH of livestock water in Akaki (6.77) is lower than that of Ambo and

Holetta. The mineral concentration of livestock water in Akaki (32.22) is higher than that of Ambo (9.82) and Welmera (3.02).

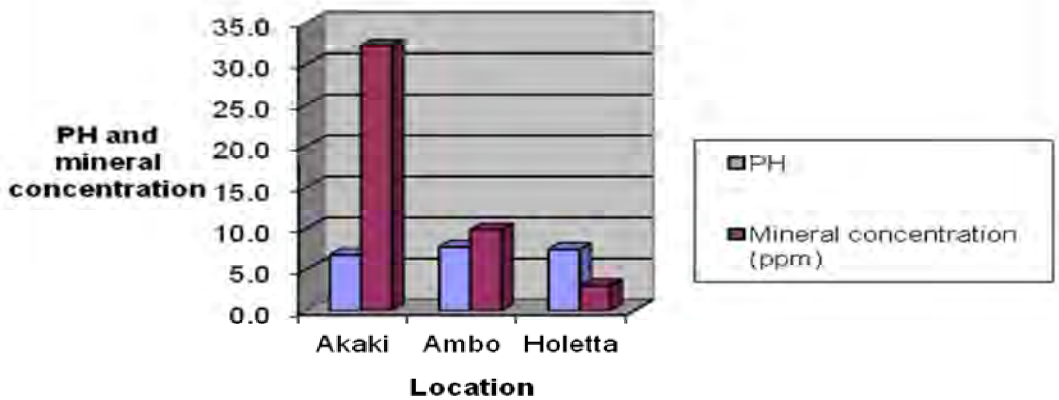

Fig. 1 PH value and mineral concentration (ppm) of livestock water across location

The concentration of mineral elements in livestock water in the study location is presented in fig 2. All mineral elements in exception of potassium constitute the highest concentration in Akaki as compared to the other study locations (Ambo and Holetta). This is in agreement with the study of Frezer (2012). He was justifying that the reason for high concentration of mineral elements in Akaki is a result of rapid urbanization, industrialization and problem of waste disposal facilities. Direct discharge of foreign materials from different sources to rivers and open lands and the leakage of industrial wastes from poorly designed septic tanks to the ground water, discharge of effluents without detoxifying the waste solid/liquid from domestic and municipal, organic matter of plant and animal origin, land and surface washing and sewage effluents are among few sources of pollution that changes the water quality. Among the mineral elements, iron concentration in Akaki has the highest value followed by calcium. Copper and zinc are the minerals recorded a lowest concentration in all the study locations.

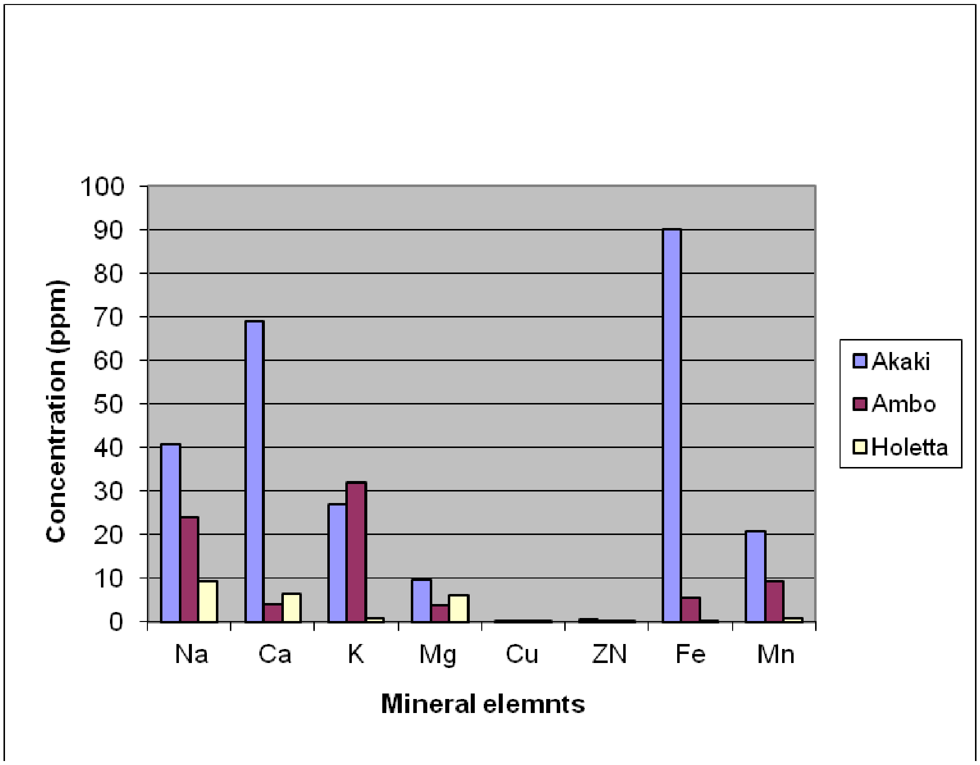

Fig 2. Concentration (ppm) of mineral elements in livestock water by location

The concentration of mineral elements in livestock water as compared to the acceptable levels is presented in table 5. Among the minerals studied, Calcium, Magesium, sodium, zinc and copper were found in satisfactory concentrations (Zinpro Water Analysis Program, 2002). Whereas the concentrations of potassium in Akaki and Ambo (31.82 and 26.91 ppm), iron in Akaki, Ambo and Holetta (89.95, 5.5 and 0.33 ppm) and manganese in Akaki, Ambo and Holetta (20.76, 3.87 and 0.83 ppm) respectively were found beyond the desired level (Zinpro Water Analysis Program, 2002). It is known that iron and manganese are very common pollutants that can occur naturally in groundwater or from nearby mining activities. Both cause severe staining and a metallic taste to water resulting in reduced water intake and reduced milk production. Iron levels greater than 0.3 mg/L and manganese concentrations exceeding 0.05 mg/L are sufficient to cause unpleasant tastes in water that may cause reduced water intake and milk production (Salinity management handbook, 2013). Low levels of iron can be troublesome in water. Levels over 0.1 mg/L have been reported to cause red meat in veal calves. Iron levels in excess of 0.3 mg/L can stain clothes. It can also support the growth of iron bacteria, which result in foul odors and plugging of water systems. As little as 0.1 mg/L iron may cause oxidized flavor in milk (Karen, 1999). Since iron and manganese are essential heavy metals, they will be toxic when they exist in excessive concentrations (Florin et al, 2008). Manganese, at a concentration beyond the acceptable level presents problems when the water is to be disinfected. It was also reported that manganese together with iron discolors fixtures. They can bring problems in restricted flow devices in drinking water lines where manganese precipitation may plug the line (Peterson, 1999). Manganese toxicity in ruminants is unlikely to occur, and there are few documented incidences with adverse effects limited to reduced feed intake and growth (Jenkins and Hidiroglou, 1991). These negative effects began to appear when dietary manganese exceeded 1000 mg/kg. The maximum tolerable amount of manganese, as given by the National Research Council (1980), is 1,000 mg/kg.

In the present study potassium is the other mineral found in excessive concentration. Since potassium is a soluble macro mineral, livestock species provided with waters of high levels may suffer with physiological upset or lead to death (Florin et al, 2008).

Table 5. Concentration (ppm) of minerals in livestock water in comparison to recommended desired and maximum upper levels

Mineral	Desired levels*	Maximum upper levels**	Concentration of minerals		
			Akaki	Ambo	Holetta
Calcium	<100	200	69.02	3.94	6.35
Iron	<0.2	0.4	89.95	5.5	0.33
Magnesium	<50	100	9.77	9.20	6.12
Manganese	<0.05	0.5	20.76	3.87	0.83
Potassium	<20	20	26.91	31.82	0.79
Sodium	<50	300	40.78	23.93	9.35
Zinc	<5	25	0.46	0.20	0.22
Copper	<0.2	0.5	0.10	0.13	0.16

Source: *Zinpro Water Analysis Program, Version 2.0, 2002.*

** Animals consuming water exceeding these limits may reduce performance*

*** The consumption of this water poses a potential animal health risk*

Table 6. Intake of mineral from water and its contribution to the daily mineral requirement of cattle

Element		Akaki			Ambo			Holetta		
	Mineral requirement of cattle, mg/d	Concentration of mineral in water mg/lt	Mineral intake from water mg/d	contribution to the daily requirement,%	Concentration of mineral in water mg/lt	Mineral intake from water/day	contribution to the daily requirement,%	Concentration of mineral in water mg/lt	Mineral intake from water/day	contribution to the daily requirement,%
Ca	5500	69.02	1173	21	3.94	67	1.2	6.35	108	2
Na	9680	40.78	693	7	23.93	407	4.2	9.35	159	1.6
Mg	59540	9.77	166	0.3	9.20	156	0.3	6.12	104	0.2
K	39872	26.91	458	1	31.82	541	1.4	0.79	13	0.03
Fe	144	89.95	1529	1061	5.5	94	65.3	0.33	5.6	4
Cu	72	0.10	1.7	2.4	0.13	2.2	3.1	0.16	3	4.2
Mn	240	20.76	353	147	3.87	66	28	0.83	14	5.8
Zn	16	0.46	7.8	50	0.20	3.4	21.3	0.22	4	25

NB. Mineral intake of cattle based on voluntary water intake of17 lt/day/animal for 0.7 TLU (180kg BW) of tropical indigenous cattle

With regard to macro minerals, the Ca content of water in Akaki can satisfy 21% of the daily requirement of cattle, while water from Ambo and Holetta can fulfill 1.2% and 2% of the daily requirement respectively (table 6). In similar study in Jijiga (Biya'ada), livestock water could satisfy about 15% of the daily mineral requirement of camel (Temesgen and Mohammed, 2012). Sodium content of livestock water from Akaki, Ambo and Holetta can satisfy 7%, 4.2% and 1.6% of the daily mineral requirement of cattle respectively. Water from Akaki was observed to be a better source of Na. In similar study in Jijiga, livestock water could contribute about 38.3% of the daily mineral requirement of camel (Temesgen and Mohammed, 2012). Magnesium content of livestock water from Akaki, Ambo and Holetta can satisfy 0.3%, 0.3% and 0.2% of the daily requirement of cattle respectively. Magnesium content in all the study sites was found to be very low. In similar study in Jijiga (Biya'ada and Golajo'o) the contribution of mineral water could contribute 1.8% and 1.3% to the daily mineral requirement of camel respectively (Temesgen and Mohammed, 2012). Potassium content of livestock water from Akaki, Ambo and Holetta can fullfill 1%, 1.4% and 0.03% of the daily requirement of cattle respectively. Potassium content in all the study sites was found to be low, particularly in Holetta was too low. In similar study in Jijiga (Biya'ada and Golajo'o) mineral water could contribute 1.2-1.6% and less than 0.001% to the daily mineral requirement of camel respectively (Temesgen and Mohammed, 2012).

Regarding the micro minerals, the contribution of Fe from water to the daily mineral requirement of cattle was found to be extremely high (1061%) in Akaki. In Ambo the contribution of Fe from water to the daily mineral requirement was also high, this was 65% (Table 6). The Cu content of water in Akaki, Ambo and Hoetta can contribute 2.4%, 3.1% and 4.2% to the daily mineral requirement of cattle respectively. In similar study in Jijiga, the Cu content of water could contribute about 8% to the daily mineral requirement of camel (Temesgen and Mohammed, 2012). The contribution of Mn from water to the daily mineral requirement of cattle was found to be very high (147%) in Akaki. As compared to Ambo (28%) and Holetta (5.8%) (Table 6). In similar study, the consumption of mineral water from Jiiga (Biya'ada) can contribute up to 18.5% of the daily requirements of Mn for the camels. The contribution of Zn from water to the daily mineral requirement of cattle in was too high (50%) in Akaki. The contribution in Ambo (21%) and Holetta (25%) was also found to be high (table 6). In similar study in jijiga (Golajo 'o) Zn content of water can contribute about 2.09% of Zn requirements of camels (Temesgen and Mohammed, 2012).

Conclusions

- There is variation in PH and mineral concentration of livestock water across the study locations. Thus, livestock water in Akaki has the highest mineral concentration and the lowest PH which was followed by Ambo and Holetta respectively.
- In some of the sub-locations sampled, extreme values of mineral concentration were recorded. This indicates that there is a wide range of variation in mineral concentration among the sub locations studied. Zero value for some mineral elements implies those elements were found to be below the detection limit of PPm.
- Mineral content of livestock water have their own contribution to the daily mineral requirements of cattle.
- Among the mineral elements studied, the concentration of potassium in Akaki and Ambo, and iron and manganese in Akaki, Ambo and Holetta were found in excessive level.

Recommendations

- For an intervention to be implemented with mineral supplementation to livestock species, the mineral status of the specific location should be taken in to consideration.
- To overcome the excessive concentration of potassium, iron and manganese in livestock water an adjustment targeting to the problematic element is required through feed/ration formulation.

- The sodium level in livestock water in Akaki and Ambo are found beyond the recommended level. Therefore, there is no need to include sodium in the feed formulation.
- Attention is required in Akaki and Ambo not to supplement feeds rich in iron and manganese to minimize the cumulative effect of these minerals coming from water and feed.
- Mineral analysis of the composition of forage feeds grown in these locations is required.

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Evaluation of EM-2 as Biological Crop Residue Treatment Option Targeted for Feeding Crossbred Dairy Cattle

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Abstract

A study was conducted at Holetta Agricultural Research Center with the objective to evaluate the effect of ensiling crop residues (wheat, barley and oat) with extended EM solution (EM2) on the nutritive value, in-vivo digestibility coefficients and animal response. Accordingly, crude protein (CP), DOMD (digestible organic matter in the dry matter), EME (estimated metabolizable energy), total ash, NDF (Neutral detergent fiber), ADF (Acid detergent fibre) and lignin (P<0.05) were significantly (P<0.05) improved by EM2 treatment as compared to the untreated straws. On the contrary, DM (dry matter) & OM (Organic matter) losses as a result of EM-2 treatment were substantial (P<0.05) for all the three residues under investigation. Barely straw was found to be higher (P<0.05) for all chemical compositions and in-vitro digestibility values except DM & OM. The rate of change calculated as percentage differences over the original untreated residue was higher for the relatively inferior quality wheat straw. From the result of the first laboratory trial, application of EM2 at the rate of 1 liter per kg straw mass have been seen to adequately improve chemical compositions and in-vitro digestibility of cereal residues. In the second trial were mid lactating Boran-Fresian crossbreds cows have been fed with either ad libtum EM2 treated or untreated barley straw and supplemented with different levels of on-station formulated dairy concentrate @ 0.3, 0.5 and 0.7 kg/liter of milk daily intake of EM2 treated barley straw was significantly improved (P<0.05) for all experimental cows other than those on the control diet. Daily total DM intake followed same trend as for the basal feed intake. Among experimental cows receiving treated straw basal diet cows on dietary T3 consumed superiorly higher (P<0.05) daily total feed intake. In general, daily intakes for all nutrients under considerations were higher (P<0.05) for cows fed the EM2 treated barley straw as a basal diet on a daily basis. While maximum daily nutrient intake (P<0.05) was recorded for cows receiving T3 lower intakes (P<0.05) were recorded for cows that have received the control diet. There was no difference (P>0.05) for apparent digestibility of DM & OM. Higher digestibility coefficients of CP, NDF and ADF were recorded for cows maintained under dietary T3. Daily milk yield and compositions except milk lactose and total solids were statistically different (P<0.05) among cows that were fed with the treated barley straw diet and when same cows were compared with those that have been fed with the untreated barley straw basal diet. Higher milk (P<0.05) was, however, produced by the cows receiving dietary T3. However, due to high cost of straw treatment compared to cows on the control diet the gross and net profit obtained from intervention treatments were marginal.

Key words: Effective Microorganism, Activated EM (EM2), barley, wheat and oat straws

Introduction

In most developing countries the feed resources for ruminant production are predominantly based on crop residues especially cereal straws. Thus the upgrading of straw quality is still a central issue as a strategy for improving ruminant livestock production (Preston and Leng, 1987). During the last two to three decades both scientists and extension workers have shown great interest in chemical and physical treatment of straw (Sundstol and Owen 1984). The ammoniation method using urea has received major attention as an appropriate system for developing countries (Owen and Jayasuriya 1989a). However, the success of ammonia treatment as well as other chemical methods in application on the farm level has generally been disappointing. There are several reasons for this, but the economic constraints may be the main one (Devendra 1991; Owen and Jayasuriya 1989b). Zhang Weixian (1994) developed an economic model for the ammonia treated straw feeding system and concluded that if the price ratio between urea-ammonia and concentrates rose above 2.5:1, this system would not be profitable. In the meantime, in many developing countries the urea: concentrate price ratio has already been close to this figure. It is therefore necessary to develop alternative treatment technologies for ruminant livestock production. Many attempts have been made by scientists to find other efficient approaches to this problem. The use of cereal-based concentrates is not a long term solution because with a large and increasing human population and limited grain production, the animal production industry in Ethiopia must direct its attention toward the use of crop residues whose total production is estimated to amount some 24 million tonnes per annum (CSA, 2014). Moreover, presently relative contribution of crop residues to ruminant livestock can be roughly estimated to rich 50% of the total produce. A promising alternative to urea treatment is a microbial fermentation method. This method is simple in application and is of low cost, and the farmer can use the same urea-ammonia treatment facilities to carry out the process. Ensiling of dry crop residues involves actions such as chopping, reconstitution of moisture, pressing and mixing with certain additives, including microorganisms such as lactic acid producing bacteria (LAB), cellulolytic bacteria, for proper fermentation and nutrient preservation. A large number of dry crop residues have been successfully ensiled with addition of microorganisms. It was shown that microbial ensilage of crop residues increased daily gains, feed intake and feed conversion, and decreased feed cost per unit gain in growing ruminants. In this regard, lactating cows fed diets based on microbial ensiled straw had increased milk and fat-corrected milk yield, and slightly higher milk fat percentages compared with diets based on untreated straw (Zhang and Meng 1995; Ma and Zhu 1997). Another significant effect of microbial ensilage of dry crop residues is probably to hydrate and weaken plant structures so that less energy is expended on rumination (Tingshuang *et al.* 2002). The technology of Effective Microorganisms as biological inoculants was developed in the 1970's at the University of the Ryukyus, Okinawa, Japan. The inception of the technology was based on blending a multitude of microbes, and was subsequently refined to include three principal types of organisms commonly found in all ecosystems, namely Lactic Acid Bacteria, Yeast

Actinomyces and Photosynthetic bacteria (Higa, 1996). The use of EM in animal husbandry is clearly identified in many parts of the world (Konoplya and Higa, 2000; Hanekon *et al*., 2001; Safalaoh and Smith, 2001).

However, although the possibility of a biological method of straw treatment has a great appeal as an alternative to the use of expensive (in terms of money and energy) chemicals and environmental pollution (Jackson 1978), so far, despite encouraging laboratory experiments, none of the microbial processes has brought an impact with farmers (Sundstol 1988). Many failures of biological straw treatment have been described in the literature, although some improvement in nutritive value seemed possible. Thus, before any new biological fermentation method is applied extensively, many aspects need further investigation. The objective of this study was hence to evaluate the new microbial inoculants EM2 as a technologically feasible alternative crop residue treatment and feeding options for dairy cattle in Ethiopia.

Methodology

Description of study areas

The study was carried out on-station at Holeta Agricultural Research Center. The center is located at 9^{o} 3’ N latitude and 38^{o} 30’ E longitudes, about 35 km West of Addis Ababa along the main road to Ambo. The study area has an altitude of 2400 meters above sea level (m.a.s.l) and receives an average annual rainfall of about 1055 mm. The mean minimum and maximum temperatures are 6.1^{o}C and 22.2^{o}C, respectively. The area is a typical mixed crop livestock production system, where small scale dairying based on crossbred animals is found here and there. The soil type in the area is largely Nitsols and major crops grown are *teff*, wheat, barley, oats, potato, field pea, faba bean and linseed.

Experimental Trials

The study consisted of two trials conducted consecutively in two major phases. The first trial was laboratory evaluation through chemical analysis and *in-vitro* OM digestibility of three major cereal crop residues namely wheat, barley and oat straws treated with extended EM solution (EM2) while the second trial has dealt with animal response feeding trial where the EM2 treated basal straw was evaluated against untreated residues using lactating crossbred cows supplemented with graded levels of on-station formulated dairy concentrate

Trial one

This trial has focused on ensiling three cereal crop residues, i.e., wheat, barley and oat straw with EM2 (extended EM solution). EM2 was prepared by mixing EM1, Molasses and Chlorine free water in the ratio of 1:1:18 respectively. 10% molasses was added to the solution to provide nutrients specifically sufficient soluble carbohydrates to the microbes in the EM2 solution, which would facilitate the ensiling process. EM2 solution was then applied to the residues at the rate of 0, 1 and 1.5 liters per kg dry matter of the residues. Except for the untreated crop residue the materials were then incubated for 30 and 40 days using airtight plastic containers using the protocols indicated in Table 1 below.

Table 1.Ensiling protocol of the three crop residues with EM2 solution

Type of crop residues	Type of treatment	Level/rate of application (liter/Kg DM)	Duration of incubation days
Wheat, Barley and Oat straws	EM2	0, 1 and 1.5	30, 40

Straws of wheat, barley and oat samples from known varieties were collected from on-station plots and subjected to chopping to an approximate size of 3-5cm.

At the end of the incubation period part of the silage mass was subjected to oven drying at 65^{o}C for about 72hours for partial DM determinations and further processing to 1mm sieve size grinding for laboratory chemical compositions and in-vitro organic matter digestibility studies.

Trial two

In this trial, the crop residue that has responded to EM2 treatment much better than the others for chemical compositions and *in-vitro* digestibility fractions from trial set-one was supposed to be selected for next *in-vivo* trial on lactating crossbred cows. According to the finding from the laboratory trial wheat straw was the appropriate candidate basal feed for the feeding trial. Unfortunately, because of luck adequate amount of wheat straw decision was made to shift the basal diet for EM2 treatment to barley straw.

Experimental Animal Preparation and Management

A total of four lactating F1 crossbred cows (Boran x Friesian) were used for this experiment. Experimental cows with similar lactation performance (8-10 lt/h/d), same stage of lactation (mid-lactating i.e., three months after calving), body weight of (393$\pm$25kg) but differing in parities (two through five) were selected from the total dairy herd available on station. All the cows were weighed and drenched with broad-spectrum anti-helminthics (Albendazole 500mg) prior to the start of the experiment. The cows were individually stall-fed in a well-ventilated barn with concrete floor and appropriate drainage slope and gutters.

Experimental Design, Treatments and Measurements

At the beginning of the experiment, four cows were randomly blocked in a simple 4X4 Latin Square Design. There were, in general, 4 experimental cows, 4 treatment diets and 4 periods. The length of each period was 28 days out of which 21 days were allocated for adaptation while

the remaining 7 days were used for actual data collections for analysis. In total, the feeding trial has taken about 112 days. All cows were hand- milked twice a day and milk yield was recorded daily. Aliquot samples of morning and evening milk was collected weekly to analyze milk chemical composition. Water was available at all times free of choice. The experimental animals were randomly allotted to one of the four dietary treatments given below.
Experimental treatments were:-

- Treatment 1: EM2 treated barley straw basal diet *adlibitum* + (0.3kg concentrate mix /liter of milk produce
- Treatment 2: EM2 treated barley straw basal diet *ad libitum*+ 0.5kg concentrate mix /liter of milk produce
- Treatment 3: EM2 treated barley straw basal diet *ad libitum*+ (0.7kg concentrate mix /liter of milk produce
- Treatment 4 (control diet): Untreated barley straw *ad libitum* + 0.5 kg concentrate mix /liter of milk produce

The cows were supplemented twice a day with a standard on-station formulated dairy concentrate mixture (76% wheat bran, 23% noug seed cake and 1% salt). The mix was assumed to fully meet the requirement for protein (20%) of lactating crossbred cows with milk yield of 8-10 liter /day and a butter fat content of 4.5% as described in ARC (1990) when fed as supplement at the rate of 0.5 kg/liter of milk.

Feed offer and refusals were measured and recorded for each cow to determine daily feed and nutrient intake. Feed offer and refusal samples were taken daily and weighed per cow, bulked on a period bases and oven dried at 65^0C for 72h. Samples were then ground using Cyclo-Tec sample mills to pass 1 mm sieve size for DM analysis to calculate feed intake.

Experimental Feeds and Their Preparation

Wheat straw was supposed to be used as a basal diet since it has responded EM2 treatment much better than barley and oat straw. Unfortunately, there was no adequate wheat straw enough to be treated for use as basal feed to experimental animals over the entire experimental period. The feed used as a basal diet in this study was hence barley straw (variety: HB1307). The concentrate was a mix prepared on-station from wheat bran, noug seed cake and salt as indicated in section 2.4 above. Barley straw collected from Holetta Agricultural Research Center was harvested by combine harvester, immediately baled and stored in hay shed until it was ready to be chopped to a size of 3-5cm using electrical chopper.

The process of ensilage begins with spraying of properly prepared EM2 solution to the barley straw at the rate of 1lt per kg straw mass. The treated barley straw was compacted and then allowed to ferment for one month in an air tight plastic barrel of (250 lt) capacity before it was being fed to the animals.

Diet Apparent Digestibility

Apparent digestibility was determined for the total ration in each treatment using the procedures of total fecal collection method for a period of 5 consecutive days at around the end of each experimental period. To minimize error in faces collections, farm personnel were assigned around the clock to scoop faeces into plastic buckets when the animals were defecating. Urinal contamination was minimized by frequent washing of the concrete floor with high pressure running water using a plastic water hose. Individual cow's faces were weighed every morning before 8:00am and before fresh feeds were given to the animals. The faeces from each cow were thoroughly mixed and a sample of 1% were taken and placed in polyethylene bag. Composite samples of the daily collected samples were mixed and stored in a deep freezer (-20^{o}C) until the end of the collection period. At the end of the collection period, the pooled samples were thawed and mixed thoroughly and samples were oven dried at 65^{o}C for 72 hours, ground to pass a 1mm sieve and stored in sample bottles at room temperature. Composite samples of EM2 treated barley straw, untreated barely straw, concentrate mix and fecal output were analyzed for DM, ash, CP, NDF and ADF. Apparent digestibility of DM and nutrients was determined using the formula:

$$Apparentdigestibility(\%) = \frac{(\text{DM or nutrient intake} - \text{DM or nutrient in feaces})}{\text{DM or nutreint intake}} \text{ X } 100$$

Milk Yield and Composition

The cows were hand- milked twice a day at 5:00am in the morning and 16:00pm in the afternoon and milk yield was recorded individually for each animal. 100ml of milk Aliquot samples from the morning and evening milking were taken every week for laboratory determination of major milk chemical compositions that includes milk fat, protein, lactose and total solids. The sampling bottle was properly cleaned and sanitized before samples were taken to Holetta Agricultural Research Center dairy laboratory.

Chemical Analysis

All samples of feeds from laboratory trial in phase one, feed offer and refusals samples from the feeding trial in phase two and faces samples from digestibility trial were analyzed for DM, ash, N (Kjeldahl-N) according to the procedures of AOAC (1990). Neutral detergent fiber (NDF), Acid Detergent fiber (ADF) and permanganate lignin were determined by the method of Van Soest and Robertson (1985). *In-vitro* organic matter digestibility of feeds offered was determined according to the procedures outlined by Tilley and Terry (1963). Hemi-cellulose was calculated as a difference between NDF and ADF. Metabolizable energy (ME) value was estimated from the *in-vitro* organic matter digestibility (IVOMD).

EME (MJ/kg) =0.16(IVOMD) according to McDonald *et al.* (2002).

Gerber method (AOAC, 1980) was used for milk fat analysis, while the formaldehyde titration method (Pyne, 1932) was used to analyze milk protein. Total solids in the milk were determined using the procedures described by Richardson (1985). Lacto scope milk product analyzer was used for lactose determination.

Statistical Analysis

Analysis of variance was made using a statistical soft ware package SAS (SAS, 2002). Data from the first trial was analyzed using CRD model in 3x3x2 factorial arrangements. All data from the feeding and digestibility trial was analyzed using a simple 4X4 Latin Square Design. Treatment means were separated using Least Squares Significant difference (LSD). The models for both designs are indicated below:

1. Model for CRD in factorial arrangement

   $Y_{ijk} = \mu + C_i + L_j + CL_{ij} + e_{ijk}$

Where;

μ = Overall mean C_i = Effect of type of crop residue L_j =Effect of level of application of EM2
CL_{ij} = Interaction effect e_{ijk} =Random error

2. Model for simple 4X4 Latin Square Design

$Y_{ijk} = \mu + C_i + P_j + T_k + E_{ijk}$,

Where: μ = Overall mean C_i = Cow effect (parity) P_j = Period effect T_k = Treatment effect
E_{ijk} = Experimental error

Results and Discussion

Chemical Compositions and *In-vitro* Digestibility of EM-2 treated Major Cereal Residues

Responses of major cereal residues to EM-2 ensiling are presented in table 1 below. According to laboratory chemical analysis, there was significant improvements (P<0.05) in the total ash and CP, NDF, ADF, lignin and DOMD contents of major cereal residues ensiled with EM2. For ash this amounts to 20.8%, 22.8% and 19.2% for oat, barley and wheat straw, respectively over their untreated counterparts. The increment for CP was 14.6% for oat, 14.2% for barley and 25.5% for wheat over the untreated residues. Similarly, percentage DOMD increments over untreated residues were 19.5%, 26.0% and 39.5%, respectively for oat, barley and wheat straw. Cell wall constituent that has shown increment by 13.6%, 27.1% & 44.7% over the untreated residues of oat, barley and wheat, respectively was hemicelluloses. On the other hand, when EM2 was used as biological inoculants there was significant (P<0.05) reductions in the DM, OM and cell wall (NDF, ADF and lignin) constituents of the residues over the untreated residues. The reduction for DM of oat, barley and wheat straw was 1.8%, 0.6% & 1.7%, respectively while it was 2.0%, 1.9% and 1.6% for OM contents of the residues in the same order as for the DM. The percentage improvement in NDF contents of the residues were 4.8%, 5.6% & 6.1% for oat, barley and wheat straw, respectively while EM has improved the remaining cell wall constituents of oat, barley and wheat straw in that order by 9.6%, 13.5% & 20.0% for ADF; and 9.30%, 25.2% & 19.6% for lignin.

Table2. Response of major cereal residues to EM2 ensiling

Treatment	Average nutritive value expressed as % DM								
	DM	Ash	OM	CP	NDF	ADF	H-cell	Lignin	DOMD
Oat untreated	93.06^{b}	8.81^{c}	91.19^{b}	1.92^{e}	80.69^{e}	63.94^{d}	16.75^{c}	9.68^{b}	38.89^{d}
Barley untreated	93.47^{a}	7.59^{d}	92.41^{a}	2.74^{b}	79.58^{d}	64.14^{d}	15.44^{d}	10.94^{bc}	38.94^{d}
Wheat untreated	93.78^{a}	7.70^{d}	92.30^{a}	1.65^{f}	82.99^{f}	65.21^{e}	17.78^{bc}	11.88^{c}	29.64^{e}
EM2 treated Oat	91.43^{d}	10.64^{a}	89.36^{d}	2.20^{c}	76.84^{b}	57.81^{c}	19.03^{b}	8.78^{ab}	46.46^{b}
EM2 treated barley	92.88^{b}	9.32^{b}	90.68^{c}	3.13^{a}	75.10^{a}	55.48^{b}	19.62^{b}	8.18^{a}	48.67^{a}
EM2 treated wheat	92.23^{c}	9.18^{bc}	90.82^{bc}	2.07^{d}	77.90^{c}	52.18^{a}	25.72^{a}	9.55^{b}	41.36^{c}
Mean$\pm$SE	92.81 $\pm$0.32	8.87 $\pm$0.42	91.13 $\pm$0.42	2.29 $\pm$0.20	78.85 $\pm$1.05	59.79 $\pm$2.01	19.06 $\pm$1.34	9.84 $\pm$0.51	40.66 $\pm$2.50
CV%	1.07	7.08	0.69	1.56	2.17	10.12	14.82	7.26	6.16

`Means with different superscripts along a column are significantly different (P=0.05)

In general, all nutritional constituents in the residues were positively influenced by EM treatment. However, above all, responses of the residues to change in ash, CP, DOMD and cell wall constituents because of EM2 ensiling were quite appreciable. Among the treated residues wheat straw followed by barley straw was considerably much influenced by EM2 treatment supporting previous notions that poor quality residues will always respond much better than residues with relatively better nutritional qualities. The reduction in DM & OM contents of EM2 ensiled crop residue from the current trial is also in agreement with previous report by EL-Tahan (2003) who pointed out that chemical composition of wheat straw, fungally treated with *Agaricus bisporus* decreased slightly the DM content compared with those in the untreated wheat straw. Salman *et al.* (2011) held an experiment that aimed to evaluate the effect of biological treatment with fungi, yeast and bacteria or their combinations on the nutritive value of sugar cane bagassie (SCB). Similar to the present finding they found a decreased DM for treated residues while the ash was observed to have been significantly ($P<0.05$) increased. Under local condition increased ash contents have also been observed by Yonatan *et al.* (2014) for coffee pulp treated and ensiled with EM solution. The decrease in the OM contents of EM treated residue from the current trial can be matched with the reports of El-Marakby (2003) and El-Banna *et al.* (2010b) who treated wheat straw and SCB with different strains of fungus *was able to* notice great decrease in content of OM for treated residues than the untreated once. The increment in ash contents for EM treated residues can be linked to the presence of molasses (reported to have high levels of minerals). Reduction in the DM and OM contents in the present trial according to El-Ashry *et al. (*2003) and Rolz *et al*. (1986) can be liked to microbial solublizing and fermentation of organic materials (mainly structural carbohydrates) as energy sources for their own growth and multiplications.

The average CP improvement over the untreated residues (i.e., 17%) from the current trial can fairly be compared with previous research findings of 19.2% for various microbial treated fibrous basal diets by Nahla *et al*. (2015) and El-Marakby (2003). Improvements made for CP contents of EM2 treated residues may be due to one of the following reasons: the presence of microorganisms, extracellular enzymes and residual media ingredients in the treated materials (Siddhant and Singh 2009; Khattab *et al.* 2013), the capture of access nitrogen by aerobic fermentation by fungus (Akinfemi, 2010), and the proliferation of fungi during degradation (Akinfemi and Ogunwole 2012).

The increments in CP contents due to EM treatment, however, were so much marginal compared to progress made with biological treatments earlier for other fibrous diets. El-Banna *et al.* (2010b) found higher CP (1.6 *vs*. 11.1%) for SCB treated with fungi. Similarly, Gado (2012) reported increased CP (1.9 Vs 11.2%) for SCB treated with a biological agent ZAD® for an ensiling period of four weeks. Additional literatures by Akinfemi and Ogunwole (2012) and Omer *et al*. (2012) reported CP contents (4.69 % Vs 7.69 %; 4.29 Vs 11.43%) all of which are by far larger than the mean CP values (1.9% Vs 2.2% for oat straw), (2.7% Vs 3.1% for barley) and (1.6% Vs 2.1% for wheat straw) recorded for EM treatment of major cereal residues from the current trial. It is a well established fact that biological treatment of poor quality roughages usually result in marked increases in CP contents when treatment conditions were appropriate. But this was not the case from the present finding majorly because of the luck of reconstituting the residues with water prior to EM applications, the difference in microbial type and strains used for biological treatment and luck of freeze drying for processing the silage material for lab analysis.

The observed increment in *in-vitro* organic matter digestibility of the residues ensiled with EM could be attributed to the reduction in percentage composition of major cell wall constituents (NDF, ADF and lignin). The yeasts and bacterial species present in the EM might have induced positive effect reflected by improvement in the corresponding *in-vitro* dry matter digestibility values of the treated residues. Especially the role of yeast in the EM solution is quite indispensable since yeasts have been reported to utilize feeds with high structural components (Maurya, 1993). The maximum improvement in DOMD% brought about by EM2 treatment over untreated residue from the current trial was the one that was recorded for wheat straw (39.5%). The average improvement over the untreated residue (i.e., 28%) was close to the figure (30%) reported earlier for coffee pulp ensiled with EM by Yontan (2014). With the exception for barley straw the *in-vitro* organic matter digestibility recorded for the other treated residues from the present trial was, however, lower than the threshold digestibility (50%) recommended for poor quality roughages by Aramble and Tung (1987). IVOMD figures as high as 57.02% recorded for rice straw treated with different strains of fungi have also been reported earlier by Akinfemi and Ogunwole (2012). Disparities in DOMD values with previous findings can be explained by the type of microbes and/or microbial strains used, quantities applied, straw type and quality and above all preconditions required to be fulfilled for biological treatment.

Application of EM inoculates on in fibrous feed stuffs have been previously reported to have increased the quality of the silage by decreasing fibrous contents of the silage (NDF and ADF) (Higa and Wididana, 2007). A decrease in NDF and ADF content of the silage could be due to the addition of molasses to the silage which in its effect can increase the number of anaerobic bacteria (lactic acid bacteria: *Lactobacillus plantarum; L.casei; Streptococcus Lactis) and* yeast (cercomycae cervicae) capable of degrading the lingo-cellulotic complexes in the cell wall fractions of the silage material through their oxidizing and solublizing effects. Several other authors were also able to note (Fayed *et al.,* 2009 and Mahrous *et al.,* 2009) similar effect by fungus that it can degrade cellulose and hemi-cellulose by oxidizing and solublizing the lignin component. In the current trial the main effect of EM as in any other probiotics for biological treatment of fibrous residues was the reduction in the cell wall constituents of the residues (see table 2 above). The result from this research work is, therefore, in agreement with earlier findings by Salman *et al.* (2011) who conducted an experiment aimed to evaluate the effect of biological treatment with fungi, yeast and bacteria or their combinations on the nutritive value of SCB. They found that the NDF, ADF, cellulose and hemicellulose contents were significantly decreased compared to untreated ones. The current result is also in pare with the findings of El-Marakby (2003) who found a great decrease in content of neutral detergent fiber (NDF- 45.1%), acid detergent fiber (ADF- by 31.5%), cellulose (by 53.7%), hemicellulose (by 96.3%) for wheat straw treated with white rot fungus *Agaricus bisporous.* Similarly, Gado (2012) and El-Banna *et al.* (2010b) had same observation with the current finding about the reduction of cell wall constituents typical of the NDF, ADF and ADL fractions after a SCB was being treated and ensiled with microbial agents such as ZAD® and brown rot fungi (*Trichoderma reesei* F-418). However, the magnitude of reduction in fiber constituents from current trial was relatively lower compared to earlier findings. Same factors mentioned above for CP and *in-vitro* OMD could be responsible for the induced variability between the present and previous findings.

Response of Crop Residues to Levels of EM2 Applications and Durations of Incubations

Responses of major cereal residues to quantities of EM2 applied per kg straw mass and days required to come up with best quality straw silage as measured through chemical compositions and *in-vitro* organic matter digestibility is shown in table 3 below. Except for DM and ash the level of application of EM2 solution per kg straw mass was non-significant (P>0.05) for all other nutritional parameters under consideration. Similarly, regardless of the difference in the ensiling periods there were no noticeable changes (P>0.05) in both chemical compositions and in-vitro digestibility coefficients except, of course, for DM & OM of the residues incubated between 30 and 40 days. In other words, there were no net gains in nutritional values by adding extra ten days beyond 30 days of incubations. Interactional effects between straws, rates of EM2 applications and incubation periods for all laboratory quality parameters considered in this particular studies were very weak and happen to remain non-significant (P>0.05).

Table3. Response of crop residues to different rates of EM2 applications and durations of incubations

Variables	Average nutritive value expressed as % DM								
	DM	Ash	OM	CP	NDF	ADF	H-cell.	Lignin	DOMD
1 Lt/Kg DM	92.58[a]	9.45[b]	90.55[a]	2.49[a]	76.48[a]	56.68[a]	19.80[a]	8.77[a]	46.23[a]
1.5 Lt/Kg DM	92.17[b]	9.97[a]	90.03[a]	2.44[a]	76.74[a]	56.97[a]	19.78[a]	8.90[a]	45.76[a]
Mean ± SEM	92.38 ±0.01	9.71 ±0.01	90.29 ±0.01	2.47 ±0.01	76.61 ±0.01	56.83 ±0.03	19.79 ±0.01	8.84 ±0.05	45.50 ±0.13
30 days of ensiling	92.04[a]	9.85[a]	90.15[a]	2.45[a]	76.72[a]	56.70[a]	20.01[a]	8.87[a]	45.50[a]
40 days of ensiling	91.71[b]	10.23[a]	89.77[b]	2.49[a]	76.50[a]	56.94[a]	19.57[a]	8.69[a]	45.49[a]
Mean ± SEM	91.88 ±0.30	9.72 ±0.09	90.29 ±0.10	2.47 ±0.01	76.61 ±0.02	56.82 ±0.02	19.79 ±0.04	8.78 ±0.29	45.50 ±0.01
Straw X EM2 X Incubation	0.103	0.106	0.106	0.073	0.917	0.231	0.554	0.138	0.061

Means with different superscripts along a column are significantly different (P=0.05)

The fact that interactional effects were non-significant has led to the decision to consider the three independent factors for the different quality parameters considered. Accordingly, the absence of statically detectable nutritional quality difference (P>0.05) for EM2 application rates can lead us to further recommendation of EM-2 at the rate of 1lt per kg dry straw mass for use on a wider scale at an on-farm level. More over, the nutritional quality of the residues treated with EM2 and subjected to incubation at two different ensiling periods (30 and 40 days) didn't happen to show any statistically (P>0.05) appreciable differences implying the need to consider 30 days of ensiling periods for EM2 treatment of cereal crop residues under field conditions. Thus considering both factors 1lt EM2/kg dry residue weight incubated for a period of 30 days can be recommended for use on a wider scale under on-farm conditions in the central highlands of Ethiopia. Since probiotic use of EM for crop residue improvement is a recent phenomenon as compared to different strains of lactic acid bacteria and fungi that have deeply studied for the last several decades literatures supporting the EM treatment option both at a laboratory and on-farm condition were quite meager.

Chemical Compositions of Experimental Feed Ingredients

The chemical compositions of feeds used for feeding trial in the present study are shown in Table 3. Higher CP continents were observed for the concentrate mix. The change in CP contents brought about by EM-2 treatment compared to the untreated straw would need to be highly appreciated. The untreated barley straw used in this study contained 27.6%, 31.7%, 15.6% and 27.6% more NDF, ADF, Hemi-Cellulose and Lignin content on DM basis than the treated barely straw, respectively. In this regard, El-Marakby (2003) for a treated wheat straw with white rot fungus *Agaricus bisporous* noticed substantial reduction in the contents of NDF by 45.1%, ADF by 31.5%, and hemicellulose by 96.3%. Samsudin, *et al.* (2013) was also able to note significant differences (P<0.05) among the EM treated rice straw and untreated rice straw in DM, OM, CP, NDF, ADF, and cellulose contents.

Table 4.Chemical compositions and in-vitro digestibility of experimental feed ingredients (% DM basis)

Feed type	DM	OM	CP	DOMD	EME (MJ/kg DM)	NDF	ADF	HC	Lignin
EMTBS	90.09	89.93	4.95	51.7	8.27	57.97	40.66	17.31	8.03
UTBS	93.4	92.39	2.30	33.1	5.29	80.05	59.56	20.49	11.05
Concentrate	89.0	92.10	20.0	68.0	10.88	40.00	21.30	18.70	6.51

EMTBS = EM treated barley straw; UTBS=untreated barely straw; HC=hemicellulose; OM= organic matter; CP= crude protein; ADF=acid detergent fiber; DM=Dry matter; NDF=Neutral detergent fiber; MJ=Mega joule; IVOMD =*Invitro organic* matter digestibility; EME= Estimated metabolizable energy

The level of DOMD and Estimated metabolizable energy (EME) contents observed for the treated barley straw was much higher than that for the untreated barely straw. However, the values were much lower compared to that observed for the concentrate mix used in this study. Akinfemi and Ogunwole (2012) also reported that EME was highest for the fungal treated rice straw than the untreated residue. Similar observations by Sommart *et al*. (2000); Nitipot and Sommart (2003) indicated that *in-vitro* dry matter and organic matter digestibility were higher for biologically treated straws than that of the untreated residues. Due to EM2 treatment the value for CP was almost doubled over the untreated residue. El-Banna *et al.* (2010a) treated potato vines with *Lactobacillus acidophilus* and reported similar improvement in CP content from15.8 to 18.5%. The improvement in CP constituent would not only sufficient enough to meet the requirement for crude protein for ideal ruminal fermentation emphasizing the need to consider additional protein supplement from the concentrate diet of lactating crossbred cows. The improvement made in cell wall fraction over the untreated residue of barley straw was quite immense. According to Singh and Oosting (1992) roughages with NDF content of 45-65% are generally categorized as a medium quality basal feed, while feeds with NDF below 45% are grouped as high quality feeds. Since intake and digestibility limitation with untreated residue can somehow be improved with EM treatment (table 5 & 6) additional saving in the daily allowance of concentrate can even be envisaged from lactating crossbred cows maintained on a basal diet of EM-2 treated crop residues.

Daily Feed and Nutrients Intake

The values for voluntarily feed and nutrient intakes of experimental cows are presented in table 5. There were considerable changes (P<0.05) in the daily basal feed intakes between the groups that fed with the treated and untreated barley straw residues. Despite clear difference in the daily allowance of concentrate as we move along the treatment set-up differences were non-significant (P>0.05) for cows under dietary treatments receiving the treated barley straw. Experimental cows receiving the treated barely straw as a basal diet consumed on average 6.62kg per day while those on the untreated residue consumed 1.76kg less barley straw on a daily basis. Daily allowance for concentrate and total dry matter intakes were significantly differing (P<0.05) both among the treatment groups that were receiving the treated residues and when these groups were compared with cows receiving the control diet.

The increasing trend (P<0.05) in the daily concentrates allowance didn't happen to influence basal feed intake among cows that received the treated barley straw. This may be due to the fact that major nutrient intakes across the cows receiving the treated straw diet might have addressed the requirement for the observed daily basal intake. However, total feed DM intake followed the rate of concentrate supplementation across the dietary treatments. It can thus be said that the improvement in the daily basal feed intake over the untreated residue seem to have been much influenced by the changes in the chemical compositions and organic matter digestibility (see table 2 & 4) of the residue brought about by EM2 treatment and the corresponding daily nutrient intakes and digestibility from the total diet.

Daily Nutrient intakes followed same trend as for the total DM intake. Differences were, in general, significant (P<0.05) both among and between dietary treatments with cows on dietary T3, exceptionally consuming considerably higher daily nutrient intakes followed by cows on dietary T2 & T1. Except for ADF intakes the increasing trend for all nutrient intakes followed the increasing trend in the daily allowance of concentrate intakes among cows receiving the treated residue. Improvements in daily nutrient intakes over the untreated residues were 1.73kg (OM), 0.27kg (CP), 0.13kg (NDF) and 31.99MJ (ME). On the contrary, because of the response of ADF residue to EM2 treatment was so marginal (see table 4) average daily intake of ADF fraction by cows receiving the untreated residue as a basal diet was higher by 0.13kg than those cows receiving the treated barely straw residue. Metabolizable energy(ME) intakes differences were highly significant among all dietary treatments (P <0.05) with cows on dietary treatment 3 consuming considerably higher daily ME contents of 15.07, 30.08 and 47.04 compared to that of cows in T2 ,T1 and T4, respectively. All cows in the current trial were, therefore, on the positive energy balance since daily ME requirement across all dietary treatments were sufficiently been met for the mean daily produced milk yield of 6.52 kg if not for the targeted daily milk yield of 8-10 kg according to ARC (1990). In other words, cows on all treatments were on the negative energy balance for the targeted daily milk yield of 8-10kg presumably because the total ration was not fortified with adequate energy sources both quantitatively and qualitatively taking in to account the quality of the basal diet.

The reason for absence of significant difference (P>0.05) for daily DM, OM, CP & NDF intakes between the cows receiving dietary T1 & T4 may be speculated to the fact that cows on the control diet even though consumed as much more concentrate mix per day (0.5kg/lt) as their counterpart cows in T1 (0.3kg/lt) had higher ADF intake that perhaps have affected digestibility and eventually daily intake of the nutrients. Secondly, it may be linked to the assumption that cows that have been fed with the treated straw had more basal feed intake and hence consequently ingested more of the nutrients which can, indeed, simply offset nutrient intakes from larger concentrate intake by the control group.

Using wheat straw and different other crop residues that are microbially treated and fed to different class of animals in China and elsewhere Wu (1996), Chen and Li (1998), Meng *et al.* (1999), and Fazeali *et al*. (2004) reported similar improvements in the daily basal and nutrient intakes for DM, OM, CP, NDF and ADF. Considerable changes in basal, total feed and daily nutrient intakes according to these authors were related to the fact that ensiled crop residues with microbial agents usually have good palatability for ruminants, and thus would be responsible for higher intake. More over according to Mekasha *et al.* (2002) the lower fiber and relatively higher CP contents in the treated residue may be responsible for the improved DM and total DM intakes by ruminants. In many experiments in comparison with ammoniated straw, microbially ensiled residues gave higher intake, faster rate of passage and therefore better performance simply because microbial agents (typically funguses and some bacteria) can effectively attack lignin and cellulose (McCarthy 1986; Fayed *et al.,* 2009 and Mahrous *et al.*, 2009). On the contrary, the finding from this trial is completely in contrast with those reports by (El-Banna *et al.* 2010a; El-Banna *et al.* 2010b; Abd El-Galil 2011) who declared negative responses for daily feed and nutrient intakes from biologically treated crop residue based diets for various classes of animals compared to the untreated residues. These variations can be associated to the difference in the microbial agent used; type of residue subjected to the biological treatment and the difference in the experimental animal unit and/or the environment under which the specific trials were conducted.

Table 5.Dry matter and nutrient intake of lactating crossbred dairy cows

	Treatments				
Intake (kg/day/cow)	T1	T2	T3	T4	SEM
Barely straw	6.65^{a}	6.68^{a}	6.54^{a}	4.86^{b}	0.17
Concentrate	1.72^{c}	3.05^{b}	4.48^{a}	2.84^{b}	0.34
Total DM	8.37^{c}	9.73^{b}	11.02^{a}	7.65^{c}	0.34
Total OM	7.57^{c}	8.80^{b}	9.99^{a}	7.06^{c}	0.31
CP	0.68^{c}	0.94^{b}	1.22^{a}	0.68^{c}	0.07
NDF	4.58^{c}	5.14^{b}	5.67^{a}	5.00^{bc}	0.16
ADF	3.02^{b}	3.28^{ab}	3.49^{a}	3.39^{a}	0.09
ME (MJ/day)	74.72^{c}	89.73^{b}	104.8^{a}	57.76^{d}	3.80

[abc]Means with different superscripts within row are significantly different (P<0.05); SEM=standard error of mean; DM = Dry matter; CP = Crude protein; NDF= neutral detergent fiber; ADF acid detergent fiber; ME = Metabolizable energy;

Apparent Digestibility of Dry Matter and Major Nutrients

The results of the effect of EM2 treated barely straw supplemented with concentrate mix on total diet apparent nutrient digestibility of lactating cross breed dairy cows are presented in table 6. Total diet apparent nutrient digestibility appeared to be significant (P<0.05) over experimental cows maintained on the control diet except for DM & OM which was observed to be non-significant both among and between experimental cows receiving the different dietary treatments. Accordingly, experimental cows that have been fed with the treated barley straw as basal diet digested on average 11.89%, 9.52% & 7.57% more CP, NDF and ADF over the cows receiving the control diet per head per day, respectively. Among cows in the intervention group, however, more nutrients except DM & OM on a daily basis were digested by cows receiving dietary T3. Compared to the control group cows on dietary T3 effectively digested more CP, NDF and ADF which was calculated to be greater by 18.6, 13.6 & 10.57 percentage units, respectively on a daily basis.

In general, it can be said that the improvements in apparent nutrient digestibility have been clearly reflected by a more and progressive daily intakes for cows that have been receiving the treated barley straw residue (see table 5). The effect of treatment shall clear be appreciated for cows maintained under dietary T1 that have consumed equivalent or even in some case more basal feed and nutrient intakes while these same cows were still receiving 200gm less formulated dairy concentrate per day compared to cows on the control group. A tendency for the increased apparent digestibility for all nutrients among cows fed with EM2 treated barely straw compared to the control group may be explained by the higher degradability rates of the treated barley straw crop residue in the rumen associated to the delignification process during the ensiling process which renders more cellulose and hemi-cellulose for microbial colonization and fermentations in the rumen. It could also be related to higher dietary total DM intake among the treated residues compared to the control group (see table 5 above).

The result from the current finding is also in par with El-Banna *et al* (2010a) and El-Banna *et al.* (2010b) who reported that the digestibility coefficients of DM, OM, CP, NDF, ADF, hemi-cellulose and cellulose of *Lactobacillus acidophilus and* brown rot fungi *Trichoderma reesei F-418* treated potato vines and SCB were higher than those of untreated potato vines and SCB. Guim *et. al. (*2000) further stated that DM digestibility percentage of EM treated silage resulted significant levels of increment in the digestibility of CP than untreated silage. Moreover, Kholif *et al.* (2005) and Mahrous (2005) in a similar finding to the current trial found that roughages subjected to fungal treatments had increased (P<0.05) digestibility for most nutrients and thus their feeding values as TDN and digestible crude protein (DCP) increased compared with untreated materials.

Crude protein digestibility among all other dietary nutrients was found to be significantly higher (P < 0.05) for cows on dietary T3 which has digested 7.14%, 13% and 21.6% more CP contents per day than cows on dietary T2,T1 and T4, respectively. This higher digestibility percentage of CP for cows under T3 might have something to do with the higher intake of concentrate mix and hence CP intake (see table 5 above) compared cows on the remaining treatments. Maseaki *et al.* (1992) noticed that biologically treated straws as well as other fibrous roughage resulted in an increase of CP content and digestibility.This result is also in line with the contention given by Gado *et al. (*2006); Khattab *et al. (*2011), that biological treatment of poor quality roughages usually result in marked increases in their CP content digestibility when the treatment conditions were appropriate.

Data analysis from the current trial showed that, for the cows receiving the intervention diet the cell wall constituents digestibility were significantly increased (P<0.05) over the untreated residues. These results are in agreement with those obtained by Abd-Allah (2007) with biologically treated corn cobs by *T. ressei* and Mahrous *et al.* (2009) compared with untreated materials. The improvement in cell wall digestibility coefficients as a result of biological treatments according to Nsereko *et al.* (2002) and Ali, (2005) may be due to the effect of increasing numbers of cellulolytic bacteria and fungi in the rumen, which may be responsible for the stepwise hydrolysis of cellulose to glucose.

Table 6.Feed DM & Nutrient Apparent Digestibility of Experimental Cows

Apparent digestibility (% DM basis)	Treatments				
	T1	T2	T3	T4	SEM
DM	47.65[a]	51.17[a]	52.57[a]	39.91[a]	4.19
OM	51.09[a]	54.51[a]	55.92[a]	45.01[a]	3.89
CP	50.01[b]	55.87[a]	63.01[a]	44.412[c]	4.44
NDF	43.93[b]	45.32[b]	50.38[a]	37.02[c]	4.2
ADF	34.62[b]	38.33[a]	40.98[a]	30.41[c]	4.38

[abc]Means with different superscripts within row are significantly different (P<0.05)

Milk Yield and Compositions

During the entire experimental periods there were no any unusual abnormalities or health problems observed on all the experimental animals due to the effect of feeding EM2 treated barely straw. Results of the effect of dietary treatments on mean daily milk yield and compositions are presented in Table 6. There were significant differences (P < 0.05) in milk yield both among and between the cows fed EM treated and untreated barely straw basal diet. On a daily basis cows that were maintained on dietary T3 produced extra daily milk of 0.55, 0.65 and 1.07 kg over those cows that were maintained on the remaining dietary treatments of 1, 2, and 4, respectively. The extra daily milk produced by cows under T3 may be justified by the relatively larger daily concentrate intake and hence protein and energy intake per head of the animal that may be over and above than supplied by the remaining treatments. Cows receiving dietary T1 produced significantly (P<0.05) more daily milk yield (0.42kg/day) over the cows receiving the control diet and the same amount of daily milk yield (P>0.05) as cows on dietary T2.

The most interesting finding from the current study was the saving in the daily concentrate allowance of 200 gram per head of cows under T1 over those cows maintained under dietary T2 & T4. When the efficiency of milk production is compared taking in to account the daily concentrate allowance for each treatment cows which were receiving T1, T2, T3, and T4 consumed 0.267kg, 0.466kg, 0.632kg and 0.472kg, respectively for each kg of milk production. This implies cows under T1 were efficient and more economical since less concentrate (0.267) was consumed to produce a kg of milk. On the contrary, cows maintained under dietary T4, even though, produced higher milk yield per day have consumed relatively more concentrate for each kg of milk produce. Before embarking on recommending any one of the dietary treatments it seems, however, mandatory to look in to the economics of the feeding so that recommendations are set based on both the biological and economic response of the cows.

The higher daily milk production among the cows that received the intervention diet can be speculated to the higher feed and nutrient intake obtained from the treated barley straw basal diet. Fazaeli *et al*. (2002) studied the effect of fungal (*Pleurotus ostreatus* coded P-41) treated wheat straw in the diet of lactating Holstein cows at 0, 10, 20 and 30% levels. Similar to the present finding they found as the daily milk yield and its composition were not affected by consumption of increasing amount of dairy concentrate. Fazaeli *et al*. from his experiment in 2004 further noted that inclusion of fungal treated straw up to 30% of the total mixed ration in late lactating Holstein cows improved the nutrients digestibility and also noted an increase in fat corrected milk yield by 13%. Some other researchers (Moawd, 2003; Khattab, *et al.* 2011) with their similar experiments that used biologically treated wheat straw and/or rumen contents fed *ad libtumly* to either lactating sheep or goats reported same findings that agree with the finding of the current trial for milk yield and compositions compared to that recorded for the untreated residues.

Cows fed with the EM treated barely straw produced higher milk fat content ($P<0.05$) than the cows in the control group. The higher fat percentage ($P<0.05$) by cows on T3 over those cows that were receiving dietary T1 & T4 can be associated to higher total DM, nutrient intake and digestibility (see table 5 & 6). Nahla *et al*. (2014) also indicated that lactating cows fed diets based on microbial ensiled straw had increased milk and fat-corrected milk yield, and slightly higher milk fat percentages compared with diet of untreated straw. Moreover, Kholif *et al.* (2014) reported increased fat contents for *Pleurotus ostreatus* treated rice straw fed lactating Baladi goats (38 and 40 *vs*. 34 g h-1 d-1) compared with those fed untreated rice straw. The improvement in fat contents of the milk produced from lactating animals fed with feeds treated with biological agents according to these researchers was perhaps linked to the increased levels of milk conjugated linoleic and unsaturated fatty acids obtained from the increased daily intake of the treated barley straw intake. Milk protein percentages also varied significantly ($P<0.05$) with cows receiving T2 & T3 having the highest protein percentage unit over those cows that were receiving the control diet. Increased dietary CP intake from the daily concentrate allowance (see table 5) might have helped experimental cows in these group generate the observed difference in milk protein. Phipps (1994) attributed higher daily milk yield and protein concentration to the high protein intakes of lactating cows. On the other hand, no considerable difference ($P>0.05$) was noticed both among the cows that were receiving EM treated barley straw as intervention basal diet and when similar groups were compared with the control group for milk lactose and total solids. It is unclear why milk sugar (lactose) was not affected both among and between the different dietary treatments despite the marked differences observed in the daily concentrate allowance of the cows existing under the different dietary treatments. It is also hardly possible to explain the absence of significant difference among all dietary treatment for milk total solids while still considerable improvements were made to other compositional parameters except for milk lactose. To this end, negative responses in daily milk yield and qualities have also been reported elsewhere. Kholif *et al.* (2014) replaced berseem clover with *Pleurotus ostreatus* treated rice straw at 25 and 45% of diets contained (CFM and berseem clover at 1:1 w/w) and found that feeding Baladi goats on treated rice straw at 25 and 45% had lowered milk yield (954 and 802 *vs*. 966 g h-1 d-1) compared to those fed un treated rice straw. Milenković *et al.* (2004) also found that replacing diets of Holstein Frisian cows with 2 and 4 kg of *Pleurotus ostreatus* spent substrate decreased milk yield (P>0.05) with the increase of participation of dry matter in dry matter of a meal. The content of solids not fat, proteins and lactose in milk decreased with increasing the level of the substrate in a meal, while the fat amount in the same trial alone was increased.

Table 7.Milk yield and composition of lactating crossbred cows

Parameters	Treatments				SEM
	T1	T2	T3	T4	
Milk yield (kg/day)	6.440^{b}	6.540^{b}	7.09^{a}	6.02^{c}	0.18
Milk compositions					
Fat (%)	3.85^{b}	3.92^{ab}	4.04^{a}	3.71^{c}	0.065
Protein (%)	2.97^{ab}	2.98^{a}	3.09^{a}	2.91^{b}	0.05
Lactose (%)	5.00^{a}	4.76^{a}	4.91^{a}	4.88^{a}	0.14
Total solids	12.41^{a}	12.40^{a}	12.45^{a}	12.43^{a}	0.10

^{abc}*Means with different superscripts within row are significantly different at (P<0.05)*

Economic Return Obtained from EM2 Treated Barely straw Feeding

Economic returns were calculated for the different groups of animals based on current price data collected for each input and out price from local markets around Holetta town (Table 8). A partial budget analysis measures those items of income and expenses that change (Stemmer *et al*., 1998). Therefore, the costs of EM2 treatment per kg straw mass, concentrate feed ingredients and the cost for treated barely straw consumed by the animals in the different treatment group were considered as varying costs while all other costs (labor for routines, medications, electricity, water etc.) were ignored since they remained constant over all the dietary treatments.

Cost benefit analysis from the table below indicated that experimental cows receiving the control diet were on the better position in terms of the gross amount of return obtained from an individual cow per day. This gross return when calculated over cows maintained on the remaining dietary treatments was more than double, i. e. 31.83, 35.83 and 33.95 more

Ethiopian birr per day over those cows maintained with the treated barely straw based diet of T1, T2 and T3, respectively. Among cows that were receiving the intervention diet differences in terms of gross and net return over control cows were, in general, not very much appreciable. Cows on dietary T1, however, generated more gross and net return over the remaining cows other than those on the control diet. More economic return by control cows can be justified by the rising cost of straw treatment with EM2 than it was originally anticipated. Moreover, the difference in the daily basal feed intake previously observed in table 5 and the resulting milk yield per day of cows receiving the intervention diet were not big enough to offset the costs for straw treatment compared to cows receiving the untreated residue. On the other hand, the relatively higher gross and net return per cow per day of cows in T1 group compared to same cows receiving treated straw based diet in T2 & T3 might have something to do with the reduction in the daily allowance of concentrate feed by 0.2 and 0.4 kg/day over same treatments, respectively. Taking the current economic benefits in to consideration feeding cross bred lactating cows with EM treated barley straw over the untreated residue seems quite unlikely unless research has come with some other alternative strategies that dramatically cut the present cost of straw treatment with EM-2 microbial solution.

In view of the above, the economic returns from the intervention diets may be higher if the positive long-term impact of EM treatment on general body condition and reproduction are also taken into account. Moreover, considering the present cost of straw treatment with EM and the market price of milk, feeding EM treated straw may be so much economically attractive if cows of high milk production potential in early lactation are fed with EM treated straws of relatively poorer quality but as the same time cheaper on the local market.

Table 8. Economic return/ cow/day of experimental cows fed the different dietary treatments

Variables	T1	T2	T3	T4
Cost variables				
EM-UBS				10.11
EM-TBS	58.39	58.65	57.42	
Concentrate	6.15	10.94	16.07	10.19
Total variable cost	64.54	69.59	73.49	20.30
Income variables				
Milk sale	67.62	68.67	74.45	63.21
Dung cake sale	24	24	24	16
Total income	91.62	92.67	98.45	79.21
Gross return	**27.08**	**23.08**	**24.96**	**58.91**
Net return /control diet	**-31.83**	**-35.83**	**-33.95**	

Assumptions

- Estimated labor cost per day was 70 birr
- Cost of 1kg treated barley straw was 8.78 birr
- An average feacal dry matter output of 4.01kg & 5.04kg for the control and cows on the intervention diets. With that assumption a cow on the control diet produced around 8 dung cakes/day while cows on the intervention diet produced around 12 dung cakes on same date.
- Sale price of a dung cake was 2 birr
- Sale price for a liter of milk was 10 birr

Summary and conclusions

In conclusion, nutritive value, intake and digestibility of crop residues can be considerably improved when a liter of EM2 solution was applied against the dry mass of a kg of the residues. Moreover, daily milk production response among the cows fed with EM2 treated barley straw basal diet can be substantially improved when lactating cows were supplemented with a dairy concentrate equal to and/or above 0.3kg/liter/day. Owning to the inflating cost of straw treatment presently it won't be economical to feed EM treated residues compared to untreated residue to lactating cows of low milk yielding potential. It is, therefore, recommended that future research work shall focus on minimizing total feed cost by: feeding EM treated residue to relatively highly responsive high producing cows, of course, by reducing cost of straw treatment mainly through reconstituting the residues with water prior to EM treatment. That way the amount and cost of EM2 used per kg straw mass can be drastically reduced. The cost of treatment and hence of feeding can further be cut to a significant level if the initial purchase price of preferred residue for EM2 treatment and ensiling is relatively cheaper. So under local condition it worth to consider wheat straw than barley and teff straw.

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The Challenge of Provision of Feed in the Semi Arid Areas, the Case of Chare and Yellen Villages of Shoa Robit, Ethiopia

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Abstract

A survey was conducted at Chare and Yellen villages in the semi arid area of Kwet District, North Shoa, Amhra regional State, Ethiopia. These villages represented the peri-urban and rural part of the district, thus enabling the assessment of the feed situation in two different agricultural production systems. Participant farmers were randomly selected in both villages. From the village household listing, ten percent from each village households were randomly selected to represent both male and female headed households. Sorghum, tef and maize are the dominant crops, and horticultural crops are also produced. Cattle, goats, sheep and camels are the dominant livestock species and grazing land is owned communally. Farm plots owned by households range between 0.5 and 2 ha, signifying the limitations to allocated land for forage cropping because the farmers prefer to grow food and/or cash crops. About 10% of the male respondents in Chare are landless, and rely on livestock for their livelihood, and access to market is not a limitation. None of the respondents cultivate improved forage crops nor allocate land as pasture in any of the cropping months. Very few farmers in Yellen plant maize as feed. Regardless of crop type, all crop residues are conserved as a dry season feed in a loose form, and no respondent stacks sorghum stalks under shade. Lack of awareness and resource were mentioned as main reason for not constructing shade for crop residues. Provision of adequate feed, especially in the dry season, remains a challenge to farmers in the villages of Chare and Yellen.

Key words: livestock, crop residues, feed

Introduction

Agriculture is a risky business particularly in areas with semi-arid type of climate. The irregularity and uncertainty of the rainfall that begins late and withdraws early is one of the main factors contributing to the low agricultural production in such areas. The low agricultural productivity makes subsistence farmers economically weak to withstand any food/feed deficit at any period of the year. Due to its specific niche adaptability, sorghum dominates other crops in terms of area coverage (128,240.06 ha) and total production (2,258,878.73 quintals) in the lowlands of North Shoa (CSA, 2013). Hence, sorghum stalk is used widely in semi-arid areas as dry season fodder.

Despite the fact that the country owns the largest cattle population in Africa 53.4 million (CSA, 2013), Ethiopia still imports milk and milk-related products. Annual per capita milk consumption in Ethiopia was recorded as 17kg per annum (Zelealem, 2013) making it one of the lowest in Africa and by far low from FAO's (1990) recommendations of 62.5 liters. The demand for milk is high in major towns of the country though the supply is too low to satisfy the demand. A shortfall in milk supplies of Shoa Robit, (one of main cities of North Shoa) is often met through milk coming from the nearby towns of Debre Birhan and Kemesse. In order to improve the milk supply and increase the income of subsistence farmers who keep a few milking cows, it is prudent first to tackle the feed shortage.

Inconsistent feed supply continues to challenge the industry. According to ELDMPS (2007) report, feed deficit of 35% occurs in normal years while the deficit rises to 70% in drought years. In Ethiopia, the major feed source comes from grazing (82%), followed by crop residues and ago-industrial by-products. The use of agro-industrial by-products at smallholder farmers' level is minimal as it depends mainly on farmers' wealth status and availability (Zinash and Seyoum, 1991). Proper utilization of crop residues as sources of feed during the dry season was reported to have brought significant change in production (Alemu *et al*.; 1991). Conserving and feeding of sorghum stalk plays a pivotal role as dry season feed in the semi-arid areas of Kewet district (Aschalew *et al*., 2014). Therefore this study was initiated and conducted to assess the feed situation of the semi arid of Kewet District by taking two distinct villages representing two different production scenarios (peri-urban and rural villages).

Materials and Methods

A survey was conducted at Kewet District of North Shoa. The district is located at longitude of 39.90^{o}E and 10.00^{o}N latitude. The major crops grown in the district include sorghum, tef, maize and different horticultural crops. Cattle, goats, sheep and camels are the dominant animals in the locality. The two villages were selected after collecting information from Development Agents and extension officers at Kewet District's Office of Agriculture. Chare village is situated 2 km away from Shoa Robit town while Yellen is located at a distance of 17 km from Shoa Robit.

Chare was selected to represent the peri-urban animal production system where milk sale and small ruminant fattening are practiced to support family income. Yellen represent rural villages where crop and livestock production are integrated and cropping system is more intensified with irrigated vegetable crops. The number of respondents was set based on the population's number of each village, where about 10 percent of the inhabitants were selected randomly and interviewed individually on a pre-set questionnaire with the help of Enumerators. Female headed households were well represented and accounted for 20 percent of the interviewed farmers. The collected data were entered in Excel data sheet and analyzed using SPSS for range and percentile values.

Results and Discussion

Of the total respondents, 19% of Chare and 18% of Yellen were female-headed households and the balance was male-headed families. Respondents' educational status varies from the illiterate at the lowest level to those with high school education, a sizeable number of the respondents were able to read and write i.e. 90% in Chare and 82% in Yellen. This indicates that Chare dwellers have better access to education than Yellen. This might be related with school distance and people awareness about the value of education (Chare dwellers live near the main city of Shoa Robit). Although all female respondents can read and write as opposed to males, the males have more chance to continue formal education through the system. Based on the study the proportion of females in Chare and Yellen that attended elementary and high school educations (Table 1) were 19 and 6 percent respectively. Cultural factors contributed much to the big difference observed, as girls are forced most of the time to marry at earlier age than boys. Overall formal education attendance reached 62% in Chare and 54% in Yellen. None of the respondents had college level education.

Table 1. Educational level of respondents of Chare and Yellen farmers in percentage

Education level	Villages					
	Chare			Yellen		
	Male	Female	Total	Male	Female	Total
Illiterate	10	0	10	18	0	18
Read and write	29	19	48	24	18	42
Grade 1- 8	29	19	48	29	0	29
Grade 9-12	14	0	14	18	6	24
>12	0	0	0	0	0	0

Twenty four percent of the respondents of Chare were under the age of 30 years, while none of Yellen respondents were in this age category (Table 2) indicating the inclination of the youth to participate in peri-urban agricultural activities compared to those living in deep rural villages of the country. With regard to age, only 19% of Chare were above the age of 51 whereas in Yellen they constitute 24%, indicating rural farmers have less chance to move out of their birth places and change work type. 80% Chare and 76% Yellen respondents were within the productive age of less than 50 years.

Table 2. Demographic characteristics of respondents

Age category	Villages					
	Chare			Yellen		
	Male	Female	Total	Male	Female	Total
< 30	24	0	24	0	0	0
31 -40	24	5	29	47	6	53
41 – 50	19	10	29	18	6	24
51 – 60	10	5	15	18	5	23
➢ 61	5	0	5	0	0	0
Total %	81	19	100	83	17	100

The average size of arable land per household was less than 2 ha and the range is from 0– 4 ha. Forty eight percent of Chare and 53% of Yellen respondents possess land between 1 and 2 ha per household (Table 3). Ten percent of Chare's male respondents do not own arable land at all (Table 3); as they were below the age of 18 at the time of the 1997 Land Redistribution Program of Amhara Regional State. The land less residents of Chare rely on livestock for their livelihood as they do have better access to markets for animal products. Yellen respondents mainly depend on rain-fed sorghum production and vegetables as they do have reliable irrigation facilities throughout a year. In both villages, no much difference was observed with regard to land ownership between female and male headed households, indicating the absence of biasness in land possession. In the highly populated zone of North Shoa land is the main factor that determines the wealth status of a family. Only 5 and 6% of Chare and Yellen respondents respectively own more than 2 hectares of land (Table 3). All cultivable land in the villages is allocated to crop production and none of the respondents' allot a piece of land as a pasture land in any of the cropping months. Farmers of both villages recognized the value of crop residue as dry season feed, and all respondents (100%) conserve crop residues regardless of crop type. None of the respondents bale crop residues; rather they conserve it in a loose form without shade and no farmer stacks sorghum under the shade. As a result, the nutritional value of this valuable feed resource is declining as times goes due to weathering. Lack of awareness and resource were mentioned as main reason for not constructing shade to conserve crop residues for longer period.

Table 3. Land holdings of Chare and Yellen respondents by sex

Land holding	Villages					
	Chare			Yellen		
	Male	Female	Total	Male	Female	Total
No land	10	0	10	0	0	0
< 1 ha	29	10	38	35	6	41
1 – 2 ha	37	10	47	41	12	53
➢ 2	5	0	5	6	0	6

Fallowing is not practiced at all in the villages and no land is allocated for hay productions during the cropping season as well no farmer allocate a piece of land for improved forage crops production. Few stands of *Leucaena* and *Sesbania* shrubs are observed around homesteads and are used to feed to preferred animals in the dry season. Similar crops are found to be grown in both villages. Sorghum is the main crop produced in the villages covering 57% at Chare and 71% in Yellen; followed by tef and onion 48 and 59 percent respectively. The region is well known with its sorghum production 14,898,156,740 quintals (CSA, 2013) next to Oromia Regional State. Respondents of Yellen produce Tef (18%) and Onion (12%) as a primary crop (Table 4). Only five percent of Chare respondents produce Mungbean and Papaya as primary crops. Five percent of Chare respondents produce tobacco as secondary crop as the village is close to Shoa Robit Tobacco Processing Plant. Using the available irrigation facility Chare and Yellen farmers produce different crops in the year. Onion at Yellen and tobacco at Chare are cash crops produced under irrigation. Though farmers were not able to quantify the exact amount, they indicated that availability of sorghum residue is high among all residues as land allocated to sorghum is proportionally high (Table 4). The stalk is fed mainly to draught oxen and milking cows in the dry period which lasts for 5 to 7 months. Any part not used for feed is used for fuel and/or construction purpose. According to CSA (2013), among the zones of the region North Shoa is the highest producer of sorghum per hectare (23.79 quintal/ha), indicating a magnificent stalk is produced as feed as the correlation between grain to stalk is high in sorghum is 1:3 respectively.

Table 4. Relative importance of crops grown in the two villages

Crop type	Chare			Yellen		
	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary
Tef	14	48	10	18	24	29
Onion	-	-	19	12	59	6
Maize	-	5	2	-	6	12
Sorghum	57	19	-	71	12	-
Tobacco	-	5	-	-	-	=
Mungbean	5	5	-	-	-	-
Papaya	5	-	-	-	-	-
Vegetables	-	5	-	-	-	-
Total	81	86	31	100	100	47

In all villages animals are raised and kept under traditional management using the low input and low output system. Cattle, goats, donkey, camel and chicken are important species found in the study area. All animals in the villages ranging from chicken to cattle are owned by small holder farmers (Table 5). In crop-livestock based system cattle are the dominant tropical livestock unit (TLU) and are kept mainly to produce replacement ox and milk. This finding is in agreement with that of Fekede *et al*., (2013) in the central highlands of Ethiopia. The higher number of oxen at Yellen primarily indicates that oxen play significant role and are used frequently for land preparation and threshing. A pair of oxen enables the farmer to manage all land preparation activities on time. Households with no or one ox may be in difficult position to timely accomplish land preparation. Twenty-four percent of both villages' respondents own one ox, while 10% of Chare farmers did not own ox at all. The majority of the respondents in both Chare 62% and Yellen 47% own a pair of oxen. Only 5 and 12% of Chare and Yellen respondents respectively own two pairs of oxen, as higher number of oxen usually corresponds to large acreage of cultivable land.

Camels and donkeys are used to transport farm products to home and market places. Though number of chickens is too small at Chare and Yellen, 0.65 and 0.06 TLU respectively they cover most of the daily/weekly expenses required by the family (Table 5). Fresh milk is either marketed/used at home or converted to butter and cheese for sale. Sheep and goats are raised to cover immediate cash needs of the household such as medicament, school fee, clothing, taxation, etc. All livestock in the locality have access to the communal grazing lands from morning to dawn regardless of sex, age and physiological stages. As per the response recorded from the farmers no management practice is employed to improve the productivity of the communal grazing land. This was due to the communal ownership that doesn't attach any responsibility to individual uses.

Table 5. Livestock types and species owned by the sample population in TLU by village and sex

Animal species	Villages					
	Chare			Yellen		
	Male	Female	Total	Male	Female	Total
Oxen	31.0	4.0	35.0	34.0	3.0	37.0
Cow	11.0	5 .0	16.0	17.0	2.0	19.0
Heifer	6.75	3.75	10.5	6.75	0.75	7.50
Steer	6.75	0.75	7.5	8.25	0.75	9.0
Calf	3.0	2.25	5.25	6.75	0	6.75
Sheep	0	0	0	3.77	0.26	4.03
Goats	1.17	1.04	2.21	39.75	0.13	7.02
Donkey	2.8	1.4	1.4	4.2	0	4.2
Camel	2.2	0	6.6	2.2	1.1	3.3
Poultry	0.46	0.33	0.65	0.05	0.013	0.06

Note: One TLU is equal to 250 kg live weight. 1 TLU = 0.25 weaned calf, 0.75 heifer and steer, 1.00 oxen and cow, 1.10 horse, 0.70 donkey, 0.13 sheep and goat, 0.013 chickens.

All respondents unanimously reported that they require additional labor to accomplish agricultural activities on time. In the vicinities labor comes usually from three sources (hired, family and shared) or a combination of them. Female-headed families in both villages required more hired labor than the male-headed families. Male-headed families of Yellen use more hired labor 47% than in Chare 33% (Table 6). This indicates that seasonality of cropping requires more labor within a given time frame and Yellen farmers are economically stronger than Chare's farmers to pay wages. Labor shortage and lack of sufficient time were reasons given for delaying collection and stacking of crop residues at the right time in both villages. This delay has its own impact on crop residues` quality, which in turn affects animal performance and farm productivity in general.

Table 6. Labor sources employed by male-and-female headed households in the two villages

Village	Sex	Labor source					
		Family	Hired	Shared	Family+ shared	Family + hired	Total
Yellen	Male	-	47	-	12	24	82
	Female	6				12	18
Chare	Male	10	33	14	-	19	76
	Female	5	-	-	5	10	19

Livestock serve as an asset and farmers are well aware of their economic importance. Animals provide immediate cash income that is required for household expenditure. Male-headed families of both villages have better chance either to own or have information about improved breeds. Respondent farmers of both villages are well aware of the value of improved breeds of cattle

(24%), sheep (6%), cattle and sheep (17%), cattle and chicken (11) and chicken only (12%). None of the respondents did not own any improved breeds at the interview time (Table 7). Consequently, the respondents clearly stated that inaccessibility to AI or bull service and improved breeds in general impedes their income.

Table 7. Percentage of respondents who previously owned improved animal breeds or have information.

Village	Sex	Animal species						
		Cattle	Sheep	Cattle + sheep	Chicken	Cattle + chicken	No idea	Total
Yellen	Male	24	-	6	12	6	35	82
	Female	-	6	6	-	-	6	18
Chare	Male	-	-	-	-	5	71	76
	Female	-	-	5	-	-	14	19

Chare respondents expend more money on feed purchase, as they do not own enough land to produce crops and use the byproduct (residues) as livestock feed or allot land for hay production. The expenditure for feed ranges from 200 to 500 Birr at Yellen, and from 300 to 1300 Birr at Chare. Prices of crop residues are usually negotiable and farmers with good economic background tend to purchase residues right away after harvest, when it is comparatively cheaper than during the dry season. All respondents complained about the escalating price of crop residues from year to year which challenges the profitability of the small enterprise that they own. This is in agreement with the findings of Binyam *et al*., (2013) who indicated that soaring feed prices destabilize milk prices in the Central Highlands of Ethiopia. The other factor of high feed expenditure noted by Chare respondents is associated with the annexation of the village with Shoa Robit City Administration that converted a large amount of arable and grazing lands to residential areas which reduces the amount of feed to be produced. As a result 67% of Chare respondents purchased additional feed while only 35% of Yellen respondents purchase feed for their animals (Table 8). In the villages water for livestock comes from rivers and pipe water, only 24% of Yellen respondents use pipe water, while the rest drives their animals to watering points.

Table 8. Percentage of respondents that purchase feed; and water availability and source in the surveyed villages

Village	Sex	Feed bought		Water availability		Drinking method	
		Yes	No	Yes	No	River	Pipe
Yellen	Male	35	67	82	-	59	24
	Female	-	18	18	-	18	-
Chare	Male	52	29	81	-	81	-
	Female	14	5	19	-	19	-

Feed availability both in quality and quantity needs a serious attention in order to fully exploit genetic potential of farm animals. Without adequate feed, productivity of animals will be hampered, and the effect will be reflected on the total farm productivity as the poorly fed oxen cannot generate adequate draught power for land preparation and other farm related operations. The respondents unanimously reported that milk production suffers from seasonal fluctuations as its production is directly related with feed availability. None of the respondents have the experience of silage making, though the technology could solve the seasonal problem of feed shortage both in amount and quality.

Although they don't cultivate them in their plots, the respondent farmers identified elephant grass, *Leucaena*, and *Sesbania* as the most popular cultivated forage crops. These species are among the improved forages reported by Ameha and Aschalew (1998) and Alemayehu (2004). The respondents clearly stated that lack of major inputs (AI or bull service, veterinary services and small farm implements), and lack of appropriate market channel hampered their farm productivity. The Office of Agriculture provides regular veterinary services and disease diagnosis although laboratory support is lacking. Strengthening the veterinary service would minimize morbidity and mortality of animals and improve the total output of the households. Labor and capital shortages are mentioned as serious bottlenecks and needs attention. Supporting private input suppliers and strengthening marketing channel can be an option to address animal related problems in the district.

Conclusion and Recommendations

Animal production is an important activity in the villages and is constrained mainly by shortage of feed, labor, capital and the ever-increasing feed price. The existing grazing lands are too poor to support any sound livestock productivity. Most of the respondents purchase additional feed to overcome the shortages during the dry season. The overall crop residues produced per household is proportional to farm size and is conserved in loose form without shade till it lasts. This practice causes loss of nutrients which is reflected on the performance of the livestock. Therefore, post harvest management of crop residues is crucial to maintain the nutritive value of these immense resources. Proper intervention mechanism in handling of crop residues enables to maintain the nutritive quality of the resources. Sorghum stalk is the main feed resource conserved as dry season feed and special attention need to be given to its conservation and utilization. Technologies like that of ensiling could be introduced and verified to improve the nutritional quality of the stalk, as the technology requires small investment that can be implemented at household level. Supporting private input suppliers and strengthening marketing channel might be an option to address animal related problems in the district.

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The Effect of Sorghum Stalk Silage Supplementation on Milk Production and Composition of Indigenous Milking Cows in the Peak Dry Season at ShoaRobit, Ethiopia

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Abstract

In the semi-arid areas of Ethiopia, utilization of sorghum stalk as feed has shown significant growth annually due to the expansion of sorghum production. Sorghum stalk is the dominant crop residue conserved in the study area and farmers mostly rely on it to feed their draught oxen and milking cows during the dry season. Sorghum stalk is conserved in loose form in open air till it lasts without shade. Such practice leads to the loss of nutritive quality due to weathering and fermentation exposures. The use of concentrates and improved forages is nonexistence due to high cost and unavailability, leaving the poorly conserved crop residues as the only source of feed to sustain productivity. This study aimed at evaluating the total yield and composition of milk produced by lactating cows supplemented with sorghum silage in the dry season. Twenty-two indigenous milking cows of volunteer farmers were allocated into two treatments (silage supplemented and un-supplemented/farmers practice). Milk yield was higher ($P < 0.05$) for cows fed with silage than the un-supplemented group. Cows that are not supplemented with silage had poor body condition, as opposed to lactating cows fed silage. Cows in the supplemented group produced on average 2.26 liters of milk per day, which was significantly higher ($P < 0.05$) than the un-supplemented group (1.16 liters per day). The silage contained better protein content (6.59%) as compared to the dry stalk (4.38). Milk fat, protein, solid-not-fat and density were not affected by the treatments ($P > 0.05$). The result indicates that conservation of sorghum stalk immediately after grain harvest in the form of silage improves milk yield.

Key Words: - Milk, milk composition, sorghum stalk, silage, indigenous milking cows

Introduction

The major feed resources for livestock at Chare village, near Shoa Robit town include natural pasture and crop residues followed by sugar cane tops and crop aftermath (unpublished data). In the dry season, the reduction of grazing pasture in biomass leaves farmers with no alternative except the wide use of crop residues. However, crop residues have low nutritive value (Seyoum *et al.*, 2007) and low digestibility (Leng, 1999). Open air storage of crop residues in stacks is common and widespread in parts of Ethiopia especially where mixed farming is practiced. In the semi-arid areas of Ethiopia, sorghum stalks are the dominant crop residue conserved as a dry season feed (Aschalew *et al*. 2014 unpublished; Tegene *et al*., 2013). Sorghum is native to Ethiopia (Ecoport, 2011), and has become the third most important cereal grain in terms of area coverage and second in terms of production (CSA, 2013). Expansion of arable land has consequently increased the use of crop residues as farm animal feed. Alemu *et al*., (1991) estimated the crop residue production of the country as 10.71 million tons per annum of which 70% of the residues is used as animal feed (Zinash and Seyoum, 1991). Significant quantity of sorghum stalk is produced every year in Kewet district, and almost all is conserved mainly as animal feed. After grain harvesting, the sorghum stalks stacked around homesteads are exposed to natural weather condition resulting in deterioration of quality. The nutritive value of stalks is influenced by weather (Kediija, 2008) and length of stacking period. The nutritive value of sorghum stalks can be preserved through silage making if properly ensiled, immediately after grain harvest (unpublished data). Ensiling ensures farmers to have quality feed to bridge the dry season feed shortage. Utilization of concentrates and improved forages in the mixed farming system of Shoa Robit do not show a lot of promise given the increasingly high cost of concentrates and land shortage for forage production .Use of alternative technologies such as silage making will have a vital role to play in planning dry season feeding strategies.

Because of the traits they acquired through natural selection over generations, indigenous livestock populations have been observed to have the capacity to use poor quality feed (Azage *et al*., 2010). In Ethiopia 98% of milk comes from the traditional system (Hizkias, 2000) and dairying is less developed and at very low level as compared to that of neighboring countries (Zegeye, 2003). Demand for dairy products is increasing in towns and cities due to large population size and high income. However, peri-urban and urban dairy farms produce only 2% of the total milk production of the country (Hizkias, 2000), and this low contribution, amongst many to the feed inadequacy both in quantity and quality (Azage *et al.*, 2006). Dairying is a strategic enterprise as a source of nutrition to households, and as income and employment generator. In order to maximize milk production at subsistence farmers level, the focus need to be given to improvement of available feeds. No research has been reported regarding milk yield and its composition from indigenous cows that fed on sorghum stalk silage, thus, this study was conducted to evaluate the performance of indigenous milking cows supplemented with sorghum stalk silage at the peak of the dry season, and how this effects milk yield and milk composition.

Materials and Methods

Site description

The experiment was conducted at Chare village, Kewet district, with longitude of 39.90^{o}E and latitude of 10.00 ^{o}N, in Northern Shoa. The site is characterized by low and variable rainfall (760.20mm/year on average, mostly raining from July to September) and high evapo-transpiration (1579mm/year) that leads to agricultural risk. The temperature, which is relatively hot, ranges from 10.9 to 29.72^{o}C, the maximum being 34.39 in June and the minimum 11.91^{o}C in January. Sorghum is the major crops cultivated in Kewet district (Bureau of Agriculture, 2013, unpublished data).

Sorghum planting, harvesting, and ensiling

Teshale, a sorghum variety released for its grain yield, was planted on a well-prepared seedbed at the onset of the main rainy season at a rate of 15 kg/ha, and was fertilized with urea and DAP at the rate of 50 and 100 kg per ha, respectively. Stalks were collected just after grain harvest and were chopped using motorized chopper to a size of 2 – 4 cm and mixed with additives (molasses and urea). To keep out any possible air entering into the silage, all pits were covered with a plastic layer before the silo was enclosed with soil and stone. Urea and molasses were used as additives since commercial inoculants and enzymes are costly and unavailable in the village.

Local tools were used to dig, fill and carry the chopped sorghum stalks in to the pit. The pits that were used in this study were dug 1m long, 1m wide and 1m deep giving a total volume of one cubic meter. Neither the floor nor the walls of the pits were cemented. Each pit was dug close to the barn to minimize labor cost and wastage at time of feeding. The silos were opened after maturation and it was found out that fermentation has taken place properly. Tests made on odor, color and smell confirmed that the silage was of good quality. Representative silage samples were collected from each silo and bulked for analysis. Samples from stacked sorghum stalks were collected from farmers' fields at 15 days interval to see if there is any change in nutrient composition during the long storage period.

Feeding milking cows

The feeding experiment was conducted on-farm using volunteer farmers having milking cows in the dry periods. Initially thirty farmers were selected from the village; out of these 18 farmers were selected to prepare 1m^3 pits and fill with chopped sorghum stalks for ensiling. Of these 11farmers were selected in the actual feeding experiment. From the 12 farmers who did not prepare silage 11 of them were used as control farmers. The twenty-two cows were grouped into two based on parity, stage of lactation and milk yield (supplemented and un-supplemented). Body weights were recorded using heart-girth measurements before and at the end of the experimental period. During the acclimatization period, silage was provided to have 10 to 20% refusal. Cows were hand-milked twice daily, early in the morning, and late in the evening, and summed each day for daily milk record. The silage was fed individually in the morning and evenings after milking until the end of the experiment. The trial consisted of a 2-week adaptation period followed by a 4- week experimental period. Milk samples of 100.00 ml were collected at the mid of the experimental period from morning and evening milking rounds for analysis.

Sample and Statistical analysis

Feed samples were dried in a forced draft oven at 60^{0}C for 72 hours, and ground with a hammer mill to pass a 1.00 mm sieve and analyzed for dry matter (DM), and crude protein (CP) according to AOAC (1990) procedures. NDF, ADF and ADL were determined by the methods of Goreing and Van Soest (1970). Milk samples were analyzed to determine milk protein, fat, SNF and density. Fat and protein contents were estimated using (O'Connor, 1994 and 1995), while the solid-not fat content was determined using Richardson, (1985) methods. The Student t-test was used for the statistical analysis of milk yield and its compositions.

Results and Discussion

Chemical composition of sorghum stalk

In the dry season, sorghum stalk is used as supplement during milking period and at enclosure time. Poor stacking method that exposes the sorghum stalk to natural calamity throughout the season results in low nutritional value. Famers usually pile sorghum stalks in open air without any cover; and have a tradition of protecting the stalks from the reach of animals using stones, wood and/or thorny acacia branches. The nutrient content of the dried stack decreases as the stalks were kept longer in an open-air without shade (Table 1). Nutrient composition of the dried stalks is low in CP and high in fibers. The CP content decreased with the period of storage reaching 4.38 within 42 days. Open-air storage without shade aggravates the nutrient composition deterioration. The higher concentration of ash observed in the silage and sorghum stack is associated with the sandy soil of the locality where there is high chance of soil contact with the feed. CP concentration of silage was high and low values of NDF, ADF and ADL were obtained with that of sorghum stack (Table 1).

In sorghum growing parts of the country sorghum stalk is used as dry season feed and at Chare it comprises the main dry season feed without any additional treatment/s. Concentration of DM, CP, ash, ADF and NDF differ among sorghum stacks collected at different periods. CP content (5.66) was slightly higher for stack collected in the first sample than the latter ones (4.38) Table (1). The sorghum stalk had higher concentration of CP, NDF, ADF and ash than reported by Seyoum *et al*., (2007).The stalk is low in its nutritive value with a digestibility of lower than 50% (Blummel *et al*., 2003) due to its low protein and high fiber content (Seyoum *et al*., 2007). The nutritive value of the stalks is influenced by the method of conservation and length of time the stalks are kept in the field. Silage nutrient content was higher than the dried sorghum stalk of the same area (Table 1). The CP concentration of the silage 6.59% was found to be high than all dry feeds and was comparable with wilted browse acacia leaves and cactus clod (Seyoum *et al*., (2007) and than that of dry grasses (Aschalew *et al*., 2014). However, the CP obtained from the silage is still lower than the minimum threshold level of 7%; below which the intake of forage is markedly reduced (Milford and Minson, 1966). Strategic protein supplementation would therefore be necessary for efficient utilization of sorghum silage at Chare village, near Shoa Robit town.

Table 1. Chemical composition of silage and sorghum stalks sampled at different dates

Sampling period	DM	Ash	CP	NDF	ADF	ADL
Before ensiling	92	11.11	5.66	71.75	45.65	26.08
Stack, 09/02/14	92	11.11	4.49	79.56	57.57	31.52
Stack, 02/03/14	92	11.11	4.38	69.5	63.09	34.78
Farmers silage	92	12.22	6.59	66.81	51.27	29.81

DM, dry matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin.

The stalk contained 65% moisture content at time of ensiling, which is in agreement with Undersander *et al*, (2003) of 65-70% moisture content for sorghum silage. The stalk CP content (5.66%) is comparable to that of Seyoum *et al*., (2007) of 5.1% harvested at dough stage and drastically dropped to 4.38% within 42days (Table 1). On the other hand, the silage CP increased to 6.59%, due to timely ensiling and urea and molasses inclusion. The sorghum silage composition presented in Table 1 is in agreement with the previous report of Aschalew *et al*. 2014) of Shoa Robit. For the resource poor farmers with limited access to commercial concentrate, the CP obtained from silage could mean a lot in maintaining or increasing milk production particularly during the dry season.

Milk yield

Silage intake at the initial stage was low and the refusal was high but stabilized to 6kg/cow/day before the end of the acclimatization period and continued with this amount till the end of the experimental period. Milk yield of supplemented and un-supplemented indigenous lactating cows is presented in Table 2. Differences in milk yield of the two groups were found to be statistically significant ($P < 0.05$) with cows supplemented with sorghum stalk silage producing higher daily milk yield than those on the control group. Similar results were also reported by Mesfin *et al*., (2009); Getu, (2008); Adebabay, *et al*., (2009) who indicated that treated crop residues produce more milk than the un-supplemented group.

The un-supplemented cows on the average produced 1.16 ± 0.48 liters milk $h^{-1}d^{-1}$, which is significantly, lower ($P < 0.05$) than the supplemented group 2.26 ± 0.48 liters. Succulence and higher CP content of the silage contributed to the significant yield difference between treatments (Table 2). The average daily milk yield performances of cows ranged from 0.5006 to 2.0877 liters with a mean of 1.16 liters for the un-supplemented group, while that of the supplemented group ranged from 1.3291 to 3.2660 with a mean of 2.26 liters per day.

The milk obtained in this study was found to be higher than the national average of 1.54liters/cow per day for the indigenous milking cows. This indicates that sorghum stalk silage can keep indigenous lactating animals on productivity without considerable drop during the dry season. Sorghum silage feeding increased lactation length and maintained the productivity of the supplemented cows during the dry season contrary to the un-supplemented cows. Under normal conditions, farmers milk their cows twice per day, early in the morning and late in the afternoon. However, farmers of Chare village milk only once in the morning in order to cope up with the dry season feed shortage. In general 64% of the supplemented cows gave two milking per day as opposed to 45% of the un-supplemented group.

Increasing number of milking days will evenly distribute the income obtained from the sale of milk in the season. This was one of the vested reasons given by the farmers for the uptake of the technology. Feeding of sorghum stalk silage in semi-arid areas could alleviate the critical feed shortage problem that usually occurs in the dry season.

The initial and final body weights of cows were not significantly different among treatments though body condition of the lactating cows seemed better for the supplemented group. As expected body weights have declined in both groups, though weight loss in supplemented group was slightly lower as compared to the un-supplemented group (Table 2). Body weight loss in the supplemented group may be due to longer period of milking than the un-supplemented group.

Table 2. Body weight and milk yield of indigenous milking cows with and without silage supplementation

Treatment	Body weight		Milk yield		
	Before	After	Daily milk	Morning	Evening
Supplemented	217±17.44	210±17.44	2.26 ± 0.48^{a}	1.40 ± 0.74^{a}	0.90±0.73
Un-supplemented	230±17.44	224±17.44	1.16 ± 0.48^{b}	0.42 ± 0.74^{b}	0.82±0.73
	NS	NS			NS

Means with different superscripts within the same column differ significantly (P <0.05). NS, not significant

Milk composition

The effect of silage supplementation and different milking time on milk composition is presented in Table 3. Silage supplementation did not significantly influence (P<0.05) the protein, fat, solid not total and density of the milk components (Table 3). However, silage supplemented lactating cows consistently produced more fat than the un-supplemented ones both during morning and evening milking hours. The lack of significant difference in milk composition (in both groups) is in agreement with the observation of Getu, (2008) and Adebabay *et al*., (2009). No significant difference was also noted between the morning and evening milking time in any of the milk components (milk fat, protein, and SNF). However, morning milking consistently produced higher levels of milk components (Table 3).

Table 3. Milk composition with and without sorghum silage supplementation

Feed type and milking time	Milk composition				
	Fat (%)	Protein (%)	SNF (%)	Density g/ml	Water added
Cows with silage supplementation					
Morning	4.44	4.08	10.01	36.53	0
Evening	3.96	3.41	8.12	28.8	9.4
Mean	4.20	3.75	9.07	32.67	4.7
Cows without silage supplementation					
Morning	3.37	4.11	10.05	36.89	0
Evening	3.07	3.36	8.04	28.67	5.2
Mean	3.22	3.74	9.05	32.78	2.63
	NS	NS	NS	NS	NS

SNF, solid not fat

NS, non-significant

Feed quality improvement resulted in increased morning milk yield. The improvement was more evident in the dry season, where feed availability both in quantity and quality is always under question under the semi arid condition of Shoa Robit. Milk yield obtained from morning was found to be significantly different with silage supplementations ($P < 0.05$), and no yield difference was obtained from evening milking (Table 2). In the study crude protein content of the silage fall below the suggested critical level of 7.0 (Table 1), this requires additional protein source to correct the deficiency. The low protein content of the dried sorghum stalk, may partly explain the low milk yield in the study. The sorghum stalk, with its low protein content (Table 1), and low dry matter intake cannot provide sufficient degradable protein for adequate microbial growth. A number of researchers found significant correlation between dry matter intake and milk production, in which high intake promotes greater supply of nutrients for milk production (Getu *et al*., (2013); Adebabay, *et al*., (2009). This technology has a role to play in the improvement of sorghum stalk where it is used as a dry season supplementary feed. Necessary inputs such as urea, molasses, plastic sheet, chopper, and knowledge are in short supply in the locality. Unavailability of these materials may slow the adoption rate, hence, strong research-extension linkage and high engagement of local administration and other concerned sectors is crucial at the initial stage to introduce the technology.

Farmers' perception about supplementary feeding

Farmers are aware of the seasonal difference in milk productivity. Sorghum silage supplement boosted production and increased household income. Though frequency of milking across the dairy production system is twice per day, Chare farmers practiced milking once a day in order to cope up with the feed shortage in the dry season. They realized that sorghum silage feeding not only maintained productivity during the peak dry season but also increased lactation length as opposed to the un-supplemented cows, which ceased milk production earlier. Unless lactating cows are supplemented with additional feed in the dry season, milk production either declines or ceases regardless of the lactation stage.

Farmers showed interest and were encouraged by the additional income they obtained due to extra milking period during the long dry season. Farmers described body condition of un-supplemented cows as relatively poor compared to the supplemented group. Milk price at Shoa-Robit, the nearest town is very high during the dry season since milk production in the area is low due to inadequate feed supply. Any cost incurred with silage preparation and feeding could be compensated by the high price of milk during the dry season with additional household income.

Conclusion

The result of this experiment indicated that good quality silage can be prepared from sorghum stalks after grain harvest at household level. Under the semi-arid conditions of Chare village, provision of sorghum silage at a rate of 6.0 kg per cow per day for indigenous lactating cows is advisable. The benefit obtained from silage feeding is satisfactory according to Chare village farmers. The improvement in milk yield performance is related to better concentration of protein, though not optimum, and succulence of the silage. Additional protein source could further improve milk yield and strategic supplementation would be necessary as sole silage does not meet the requirement of the lactating cows. Therefore, further work is needed to device specific supplements and additional protein sources to complement silage supplementation for increased milk production. So far, assistance to dairy development is focused on highland areas close to urban areas. Based on the outcome of this study, it is suggested that emphasis should be given to pocket lowland areas where milk production could be cost effective.

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Studies on the Effect of Wet Castor Leaf Feeding and Feeding Frequencies on Economic Traits of Eri-silkworm, *Samia cynthia ricini* Boisduval (Saturnidae: Lepidoptera)

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Abstract

The study was carried out at Melkassa Agricultural Research Center in the sericulture and apiculture research laboratory during 2012 and 2013G.C. cropping seasons. Both tender and matured castor leafs were obtained from Melkassa Agricultural Research Center, sericulture research field to investigate the effects on castor feeding silkworms. During young age (1st and 2nd instars) rearing the tender leaf and late age (3rd, 4th and 5th instars) rearing matured castor leaf were dipped in the water and excess water was drained out by shaking and fed to the silkworms as per the treatments. The young age (1st and 2nd instars) silkworms were fed with daily once (8 am), twice (8 am and 8 pm) and thrice (8 am, 2 pm and 9 pm).While late age (3 rd, 4th and 5th instars) silkworms were fed with daily twice (8 am & 8pm), thrice (8am, 2pm and 8 pm) and four times (8am, 12 noon 4 pm and 9 pm). The control batch silkworms were reared as per the standard rearing practices. The experiment was laid out in a randomized block design in three replications with a disease free laying per replication. Rearing of castor feeding silkworm by giving tender wet leaf daily twice at young age (1st and 2nd instars)) and matured wet castor plant leaf daily thrice for late age (3rd, 4th and 5th instars) silkworm significantly reduced the larval duration and diseases incidences and improved all the larval, cocoon and silk traits as compared to other feeding frequencies. While, the recommended normal three times/day castor leaf feeding at young age (1st and 2nd instars) and normal three times/day castor leaf feeding at late age was inferior in larval, cocoon and silk traits.

Key: - *Samia Cynthia ricini, Cocoon traits, Feeding frequencies, Wet leaf*

Introduction

Silkworms, lepidopteran insects have a great economic importance for its natural protein fibers. One among the domesticated commercialized silkworms is the er-silkwom, *Samia Cynthia ricini* Boisduval (Saturnidae: Lepidoptera). Though the insect is a polyphagous insect, the primary food plant of the insect from which it drives its nutrition is castor plant, Recinus communis (Nagaraju, 2002). Castor (Ricinus communis) is the principal host plant of erisilkworm (*Samia Cynthia ricini*) (Chowdhury, 1982). The rearers of erisilkworm largely depends upon the use of castor leaves in conducting rearing as it produces the best result in respect of qualitative and quantitative characters of the erisilk.

The quality and quantity of castor leaves, therefore, play an important role in growth and development of eri-silkworm, particularly during adult and larval stages, which in turn influence the cocoon productivity and the economic traits of the cocoon. Good quality and sufficient quantity castor leaves feeding to the developing worms leads to an increase in body size and dry weight of cellular mass which are dependent on the rate of metabolism, absorption of nutrients, and stage of development (Rajanna, 1991).

The nutritional elements of castor leaves determine the growth and development of the larvae and cocoon production (Seidavi *et al*., 2005). The quality and quantity of the leaves has a profound effect on the superiority of silk produced by S. c *recini*. Leaves of superior quality, free from diseases and dust, enhance the chances of good cocoon crop (Ravikumar, 1988). It has also been demonstrated that the dietary nutritional management has a direct influence on quality and quantity of silk production in eri-silkworm (*S.c.recini*) (Murugan *et al*., 1998).

Castor feeding silkworm is a voracious feeder during the last two instars and requires to be fed many times for better and uniform larval growth and development. Castor leaf quality, time of harvesting, method and duration of storage of castor, feeding method, way of chopping, appetite of silkworms, silkworm breeds / hybrids, larval instar and temperature and relative humidity existing in the rearing room are known to decide the feeding frequency in silkworm rearing so as to harvest better cocoon crops. Quantitative differences in feed influence both the larval growth and cocoon character in eri-silkworm (*S.c.recini*). It was known that silkworm consumes 14% and 80% of the total quantity of leaf required in IV and V instars, respectively. As per the environmental conditions of different seasons, feeding is given two times per day in rainy season, while three times per day in rainy season, while three times during winter season and summer seasons (Krishnaswam *et.al*, 1980)

Matsumara *et al.*, (1958) and Joshi KL.(1992) opined that quality of castor leaves contributes 38.20 per cent for quality cocoon production. Quality of castor leave is determined by its moisture retention capacity and nearly 75 per cent of water content in castor leaf was found to influence the dietary efficiency of silkworm (Rajendran *et al.*, 1993). In tropical climate, castor leaves loss considerable amount of moisture during storage and on the rearing bed before they are actually fed by silkworms due to high rate of transpiration. In order to conserve the leaf moisture and to maintain the freshness of the leaves, the sericulture farmers of most Indian and Chinese used to dip both castor and mulberry leaf in the water before feeding to silkworms (Rayar, 2001). Ethiopia in general and Malkassa Agricultural Research Center in particular are parts of tropical climate and castor leaf moisture evapo-transformation is very high and changes the leaf to unpalatable form for the silkworms. The literature and scientific data pertaining to the effect of wet castor leaf feeding and feeding frequencies on the rearing performance of eri-silkworm are scanty and hence the present study.

Material and Methods

The experiment was conducted at Melkassa Agricultural Research Center in the sericulture and apiculture research laboratory during 2012 and 2013 cropping seasons. The objective of the experiment was to investigate the effect of tender and matured wet castor leaf feeding and feeding frequencies on eri-silkworms larvae, cocoon and post cocoon traits. Castor cultivation and eri-silkworm rearing was carried out as per the recommended agronomic practices and standard rereading procedures (Krishnaswami *et al*., 1978a; 1978b). The experiment was laid out in a randomized block design in three replications with a disease free laying per replication. The eri-silkworm rearing was carried out both during winter and summer season. For young age (1^{st} and 2^{nd} instars) rearing, tender leaves and for the late age (3^{rd}, 4^{th} and 5^{th} instars) rearing matured castor leaves were dipped in the water and excess water was drained out by shaking and then fed to the eri-silkworms as per the treatment details (Table 1). The young age eri-silkworms were fed with wet castor leaves daily once (-at 8 am-), twice (-at 8 am and 8 pm-) and thrice at (-8 am, 2 pm and 9 pm-). While late age eri-silkworms were fed with wet castor leaves daily twice (8 am & 8pm), thrice (-8am, 2pm and 8 pm-) and four times (8am, 12 noon, 4 pm and 9 pm). The control batches, eri-silkworms reared as per the standard rearing practices, were maintained for comparison. The data on growth and development of larvae, cocoon traits, post cocoon traits and disease incidence and severity were collected for each rearing. Data were pooled and analyzed as suggested by Gomez and Gomez (1984).

Larval weight: - The mean larval weight (g) recorded for 10 randomly selected larvae at peak of growth of fifth instars larvae from each replication. This was indicator of the general health of the larvae.

Larval duration: - The period covered from hatching of an egg to 5^{th} instar larval spinning refer to larval duration.

Effective rate of rearing:- $ERR\ (\%) = \dfrac{Number\ of\ \ cocoon\ harvested}{Total\ \ number\ \ of\ \ larvae\ brushed} x100$

Filament length: - This the most important parameters used by industry. Silk filament length indicates the reelable length of the silk filament from a cocoon. It was calculated using the average length of unwound silk filament from 10 cocoons (obtained using a mono cocoon reeling unit) and expressed in meters according to the following formula.

Filament length=

$$Filamentlength = \frac{length\ \ raw\ silk(m)x1.25(circumferance)}{No\,of\ reeling\,cocoon}$$

Rendita:-

Cocoon Quality Index (CQI) defined as numerical measure or an expression of the totality of its quality feature.

$$CQI = -8.5 + 0.682(SR\%) - 0.414(defective\ cocoon)$$

Rendita=$Filment\ length = 8.5 - 0.6 * CQI\ if\ CQI > -1.0$

Rendita=$Filment\ length = 9.5 - 0.6 * CQI\ if\ CQI < -1.0$

Cocoon shell ratio: - The total quantity of silk available from a single cocoon was expressed as a percentage of using the following equation:- (Single coccon shell weight)(g)/ (single coccon weight (g)) x100

Cocoon weight (g):- The average single cocoon weight in grams chose randomly on the 6^{th} or 7^{th} day of spinning.

Cocoon yield for 10,000 larvae:- The mean number of cocoons harvested relative to the number of larvae at the beginning of the experiment, coverted to 10, 000 larvae.

Cocoon yield by weight (kg) for 10,000 larvae: - The mean weight of the cocoons harvested in kilograms (kg) for every 10,000 larvae by weight.

Pupal weight (g):- The average single pupal weight come out from cocoon in grams chosen randomly on the 6^{th} or 7^{th} of spinning.

Shell weight (g):- the average single cocoon shell weight in grams for 10 cocoons chosen randomly. The shells used were the same cocoon used for cocoon weight determination.

Dinier (d):- The thickness of the silk filament measured by following formula.

$$Dinier = \frac{weight\ of\ total\ filament(g) * 9000}{Total\ total\ filamentlength}$$

Data collected from all experiment with three replications were subjected to statistical analysis. Two way analysis of variance (ANOVA) was carried out to find out the significant differences between the feeding. Multiple comparison of means were made depending on F ratio and critical differences values based on student t critical at 5% level of significances.

Results

Larval Duration

Young age larval duration (251.96h) and total larval duration (611.83 h) was significantly shorter in two times wet castor leaves feeding at young age plus three times matured wet castor leaves feeding/day at late age as compared to 262.95 and 654.63 h in three times tender leaf feeding at young age plus three times normal matured castor leaves feeding/day at late age, respectively. Furthermore, the young age larval duration with two times tender wet castor leaf feeding at young age + two times matured castor leaves feeding/day at late age (252.35 h) and two times tender wet castor leaf feeding at young age + four times matured wet castor leaf feeding at late age (252.55 h) were on par with two times tender wet leaf feeding at young age + three times matured wet leaf feeding/day at late age.

Larval weight, ERR, Pupal weight

The young age larval weight (1.527 g/10 larvae), mature larval weight (46.300 g/10 larvae) and effective rate of rearing (83.66%) were significantly highest in two times tender wet leaf feeding at young age + three times matured wet castor leaf feeding/day at late age as compared to 1.157 g, 33.303 g and 70.66 per cent, respectively, in three times normal leaf feeding at young age + three times normal matured leaf feeding/day at late age. The highest pupal weight (18.720 g/10 pupae) was recorded in two times wet tender leaf feeding at young age + three times wet matured leaf feeding/day at late age, as compared to 13.463 g/10 pupae in three times normal tender leaf feeding at young age + three times normal matured leaf feeding/day at late age (Table1).

Disease incidence and severity

Per-centage defective cocoons (5.20%), grasserie (3.75 %) and flacherie (4.08%) disease infection were significantly lower in two times wet tender leaf feeding at young age + three times wet matured castor leaf feeding/day at late age as compared to 9.32, 6.25 and 6.83 per cent, respectively, in three times normal leaf feeding/day both at young and late age (Table 3).

Cocoon and post cocoon traits

The eri-silkworms reared by feeding wet castor leaves two times and three times per day at young age produced the highest cocoon yield/10,000 worms (20.58 kg), cocoon yield by number per 1000 worms (837), cocoon weight (23.020 g/10 cocoons), cocoon shell weight (4.317 g/10 shells) and cocoon shell ratio (18.83%) as compared to other treatments. While it was 15.47 kg, 707, 16.083 g, 2.603 g and 16.11 per cent, respectively, in three times tender normal leaf feeding at young age + three times normal castor leafs feeding/day at late age (Table 2).

The highest silk productivity (6.25 cg/day), single cocoon filament length (959.66m) and finer denier (2.58) was recorded in two times tender wet leaf feeding at young age + three times wet matured mulberry leaf feeding/day at late age as compared to other treatments. While, three times normal castor leaf feeding at young age + three times normal matured castor leaf feeding/day at late age recorded lowest silk productivity (3.14 cg/day), shorter silk filament (688.10 m) and coarser denier (2.89). Similarly, the rendita was superior in two times tender wet mulberry leaf feeding at young age + three times wet matured mulberry leaf feeding/day at late age (7.23) and two times wet castor leaf feeding at young age + four times wet matured castor leaf feeding/day at late age (3rd, 4th and 5th instars) (7.25) and were on par with each other. While, the rendita was inferior in three times tender leaf feeding at young age + three times normal matured leaf feeding/day at late age (7.90) (Table 3). The results clearly reveals the superiority of tender wet leaf feeding to the young age and wet matured castor leaf feeding to late age silkworms over normal leaf feeding. Among the different tender and matured wet leaf feeding frequencies, two times tender wet leaf feeding at young age +three times wet matured leaf feeding/day at late age was found to be significantly superior.

Discussions and conclusion

Rearing of silkworms with different feeding regimes caused marked influence on late age larval duration and total larval duration but had no effect on young-age worms. These results are supported by Haniffa *et al.* (1988) who reported that when the numbers of feeds were restricted from 8 to 1/day, the larval period was extended. Krishnaswami *et al.* (1980) also observed prolongation of larval period as a result of under feeding. The larval duration in the present study has almost followed the trend observed by the previous workers (Das *et al*., 1994; Chandrashekar, 1996).

The current study indicated the superiority of wet leaf feeding over the others treaments and this may due to the maintenance of leaf moisture at optimum level for longer time on the rearing bed, thus making the leaves more palatable for silkworms. Ito (1963) and Yokoyama (1974) indicated that higher leaf moisture is known to increase the amount of leaf ingestion and digestion capacity of silkworm. Parpiev (1968) reported the increase in palatability and assimilation of nutrients due to high leaf water content. Soaking and spraying of leaves with water both during winter and summer has increased the cocoon and shell weight in bivoltine and multivoltine silkworms (Anon., 1993). Similarly, Rayar (2001) reported that, the reduction in larval duration and improvement in cocoon and silk traits by feeding wet matured leaf daily thrice to late age (3rd,4th and 5th instars) silkworms during winter season and confirm the present observation. Dipping the leaf in water also removes the dust and dirt present on the leaves and making it more hygienic to silkworms for feeding. The current observations are also supported by the previous findings wherein, wet feeding 3 times/day from third instar onwards resulted in higher silk ratios, dinier and lower diseases incidence compared to lower feeding per day. Similar results as at present were observed in the past (Das *et al*., 1994). Even in silkworm hybrids, NB18 x NB7 and

PM x NB18 the schedule of 2feeds/day in young age followed by 3 and above feeds/day in late-age silkworm rearing resulted in higher cocoon yield (Anon., 1987).

Rearing of castor silkworm by feeding tender wet castor plant leaf daily twice at young age and matured wet castor plant leaf daily thrice to late age has significantly reduced the larval duration and diseases incidence and improved all the larval, cocoon and silk traits as compared to other feeding frequencies. Our study confirmed that two times feeding/day tender castor leaf for young age silkworms and three times feeding/day wet matured castor leaf for late age silkworms can be effective rearing practice for the silk worms.

Table1. Effects of wet castor leaf feeding and frequencies on **growth and development** of eri-silkworms, *Philosamia recini*

Treatments	**Young age Larval duration (h)**	**Young age larval weight (g/10 larvae)**	**Matured larval weight (g/10 larvae)**	**Total larval duration (h)**	**Effective rate of rearing (%)**	**Pupal weight (g/10 pupae)**
1 time/day tender wet leaf at young age + 2 times matured wet leaf feeding/day at late age (T_1)	257.33bcd (10.72)	1.193ef	39.247f	631.79e (26.32)	75.75 (60.87)c	14.017g
1 time/day tender wet leaf at young age + 3 times matured wet leaf feeding/day at late age (T_2)	258.50d (10.77)	1.210ef	41.033c	626.25c (26.09)	76.00 (61.04)c	14.357fg
1 time/day tender wet leaf at young age + 4 times matured wet leaf feeding/day at late age(T_3)	258..03cd (10.75)	1.243e	41.450c	626.32c (26.09)	75.83 (60.91)c	14.883e
2 time/day tender wet leaf at young age + 2 times matured wet leaf feeding/day at late age(T_4)	252.35a 10.51	1.417b	39.543ef	629.40c (26.22)	75.75 (60.86)c	14.653ef
2 time/day tender wet leaf at young age + 3 times matured wet leaf feeding/day at late age(T_5)	251.96a 10.49	1.527a	46.300a	611.83a (25.49)	83.66 (66.91)a	18.720a
2 time/day tender wet leaf at young age + 4 times matured wet leaf feeding/day at late age(T_6)	252.55a 10.52	1.407bc	44.380b	617.92b (25.74)	78.00 (62.76)b	17.970b
3 time/day tender wet leaf at young age + 2 times matured wet leaf feeding/day at late age(T_7)	256.12b 10.67	1.350d	39.803def	629.01d (26.20)	76.00 (60.99)c	15.397d

3 time/day tender wet leaf at young age + 3 times matured wet leaf feeding/day at late age(T_8)	255.99b 10.66	1.360cd	39.950de	627.00c (26.12)	76.16 (61.06)c	16.270c
3 time/day tender wet leaf at young age + 4 times matured wet leaf feeding/day at late age(T_9)	256.62bc 10.69	1.337d	40.347d	627.17c (26.13)	74.75 (60.11)d	15.163e
3 time/day normal leaf at young age + 3 times normal leafs feeding/day at late age(T_{10})	262.95e 10.95	1.157fg	33.303g	654.63f (27.27)	70.66 (57.63)e	13.463h
S.E±	**0.939**	**0.037**	**0.440**	**0.674**	**0.394**	**0.332**

Within column, means followed by similar letter are not significantly different (CD=0.05) by DMRT, T= treatment

Table2. Effects of wet castor leaf feeding and frequencies on **cocoon traits** of eri-silkworms, *Philosamia recini*

Treatments	**Cocoon yield/10000 larvae's(kg)**	**Cocoon yield (cocoons/1000 larvae)**	**Cocoon weight (g/10 cocoons)**	**Cocoon shell weight(g/10 sheels)**	**Cocoon shell ration (%)**	**Rendita**
1 time/day tender wet leaf at young age + 2 times matured wet leaf feeding/day at late age (T_1)	16.56d	753de	17.021f	2.837f	17.07f (24.36)	7.35c
1 time/day tender wet leaf at young age + 3 times matured wet leaf feeding/day at late age (T_2)	17.33c	760c	17.543ef	3.190c	18.09b (25.25)	7.32b
1 time/day tender wet leaf at young age + 4 times matured wet leaf feeding/day at late age(T_3)	17.29c	758c	17.993de	3.080cd	17.20cd (24.44)	7.30b
2 times/day tender wet leaf at young age + 2 times matured wet leaf feeding/day at late age(T_4)	17.26c	757cd	17.140f	2.900ef	16.81cd (24.17)	7.31b
2 times/day tender wet leaf at young age + 3 times matured wet leaf feeding/day at late age(T_5)	20.58a	837a	23.020a	4.317a	18.83a (25.67)	7.23a
2 times/day tender wet leaf at young age + 4 times matured wet leaf feeding/day at late age(T_6)	18.02b	780b	21.753b	3.847b	17.87b (24.96)	7.25ab
3 times/day tender wet leaf at young age + 2 times matured wet leaf feeding/day at late age(T_7)	17.07cd	760c	18.490d	2.983de	16.06e (23.57)	7.27b
3 times/day tender wet leaf at young age + 3 times matured wet leaf feeding/day at late age(T_8)	17.38c	762c	19.397c	3.107cd	16.29de (23.75)	7.29b
3 time/day tender wet leaf at young age + 4 times matured wet leaf feeding/day at late age(T_9)	16.87cd	748e	18.051de	3.013de	16.55cd (24.00)	7.31c
3 times/day normal leaf at young age + 3 times normal	15.47e	707f	16.083g	2.603g	16.11e	7.90d

leaf feeding/day at late age(T_{10})					(23.55)	
S.Em±	**0.164**	**3.631**	**0.373**	**0.089**	**0.278**	**0.013**

Within column, means followed by similar letter are not significantly different (CD=0.05) by DMRT, T= treatment

Table3. Effects of wet castor leaf feeding and frequencies on **silk traits and disease incidence** of eri-silkworms, *Philosamia recini*

Treatments	**Silk traits**			**Disease incidence (%)**		
	Silk productivity Cg/day	**Single cocoon filament length (m)**	**Denier**	**Defective cocoon**	**Grasserie**	**Filacheries**
1 time/day tender wet leaf at young age + 2 times matured wet leafs feeding/day at late age (**T_1**)	3.73d	770.23e	2.73c	8.81bc (17.20)	5.91cd (13.74)	5.59bcd (13.05)
1 time/day tender wet leaf at young age + 3 times matured wet leaf feeding/day at late age (**T_2**)	3.98c	784.76cd	2.71c	8.97bc (17.07)	6.50def (14.43)	8.17cde (13.53)
1 time/day tender wet leaf at young age + 4 times matured wet leafs feeding/day at late age(**T_3**)	4.12c	780.71cde	2.72c	8.52b (16.48)	5.91cd (13.61)	5.50bcd (12.73)
2 times/day tender wet leaf at young age + 2 times matured wet leafs feeding/day at late age(**T_4**)	3.75d	756.72f	2.71c	9.76cd 17.97	5.58bcd (13.39)	5.25bc (13.11)
2 times/day tender wet leaf at young age + 3 times matured wet leafs feeding/day at late age(**T_5**)	6.25a	959.66a	2.58a	5.20a (12.93)	3.75a (10.55)	4.08a 10.91
2 times/day tender wet leaf at young age + 4 times matured wet leafs feeding/day at late age(**T_6**)	5.37b	895.24b	2.62b	7.69b (16.32)	5.75bc (13.23)	4.91b (12.79)
3 times/day tender wet leaf at young age + 2 times matured wet leafs feeding/day at late age(**T_7**)	3.83d	778.32de	2.70c	8.45bc (16.63)	4.83b (12.38)	6.16def 13.82
3 times/day tender wet leaf at young age + 3 times matured wet leafs feeding/day at late	4.04c	791.35c	2.71c	8.52b (16.61)	5.91bcd (13.38)	5.75cde (13.58)

age(**T_8**)						
3 time/day tender wet leaf at young age + 4 times matured wet leafs feeding/day at late age(**T_9**)	4.08c	790.55cd	2.71c	8.51bc (16.56	6.91ef (14.93)	6.66efg (14.26)
3 times/day normal leaf at young age + 3 times normal leafs feeding/day at late age(**T_{10}**)	3.14e	688.10g	2.89d	9.32bcd 17.52)	6.25def (13.94)	6.83fg (14.77)
S.Em±	**0.093**	**7.826**	**0.017**	**0.858**		

Within column, means followed by similar letter are not significantly different (CD=0.05) by DMRT, T= treatment

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Effect of *Ficus sur* fruits supplementation on rumen ammonia nitrogen, pH concentration, and blood profile of Hararghe highland sheep fed natural pasture hay basal diets

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Abstract

The experiment was conducted for 90 days in Haramaya University to evaluate the rumen ammonia nitrogen, rumen pH concentration, and blood profile of Hararghe highland sheep consumed natural pasture hay (NPH) basal diet supplemented with varied proportions of ground Ficus sur fruits (FSF) and ground oats grain (OG) diets at isonitrogenous level provision of noug seed cake (NSC) (Gizotia Abysinica). The treatment diets were ad libitum natural pasture hay (control); 100%FSF:0%OG [100FSF]; 67%FSF:33%OG [67FSF]; 33%FSF:67%OG [33FSF]; 0%FSF:100%OG [0FSF]. The experiment was laid out as a Randomized complete block design. Four animals from each treatment were used to collect about 30-40ml of rumen fluid using stomach tube at 4 hours post feeding for ammonia nitrogen (NH_3-N) and pH profile determination. Additional rumen fluid samples were taken at 0, 2, 4, 8, 12, and 24 hours post feeding for rumen fluid pH dynamics determination. About 10 ml of blood sample was taken from jugular vein of the sheep and RBC, WBC and hemoglobin concentration were determined by employing the Neubauer counting chamber. The packed cell volume (PCV) was determined by spinning blood field capillary tubes in a microhematocrit centrifuge and reading the value on heamatocrit reader (model AIC 1490). Sera components were determined using spectrophotometer and refractometer. The mean cell volume (MCV), mean cell haemoglobin (MCH), and mean cell haemoglobin concentration (MCHC) were calculated from the PCV, Hb, and RBC count. The study indicated that feeding Ficus sur fruits (FSF) at varied proportion with ground oats grain (OG) resulted in nearly neutral rumen liquor pH (7.12-7.24), optimum NH_3-N concentration (84.7-85.7mg/l), and normal count of WBC (11.5-12.71^3/µl), RBC(11.0-11.51^6/µl), optimum levels of PCV (36.7-40.8), Hgb (11.8-13.3 g/dl), and sera metabolites, which all indicated healthy rumen and cardiovascular physiology. Hence, FSF can be used as a source of energy ingredient, in replacement for OG, as the present study proved that it has positive effect on rumen environment and blood profile of lambs.

Keywords: Ammonia nitrogen, blood profile, pH, rumen fluid, Hararghe highland sheep

Introduction

In multi-cellular organisms, different biological systems jointly function to help the organism perform normal physiological activities. For example, the digestive system provides soluble nutrients which are absorbed from small intestine into the hepatic portal vein of the cardiovascular systems (Breves and Wolffram, 2008; Barej et al., 1980) so that every cell at the periphery can get nutrients through the blood transport system. One of such nutrients is ammonia nitrogen (NH3-N). Consumption of diets containing excess nitrogen concentration, upon degradation, results in release of higher level of ammonia (McDonald et al., 2002). If too much ammonia is released within a short period, the ammonia level in the blood rise and become toxic and the pH in the rumen simultaneously rises to the extent that rumen ceases to function normally (Nauhaus, 2008).

Among many other roles, the blood functions in nutrient transport, protection against pathogens, and regulation of optimum conditions (temperature, pH and body water balance). The excess or deficiency of nutrients in the blood above or below the normal concentration level could be an indication of some nutritional disorders or abnormal hematological physiology (Zvonko Antunović et al., 2011; Ogbuewu et al., 2010; Van Saun, 2000).

In feed quality evaluation, some of the most common practices include laboratory chemical analysis (Cherney, 2000); intake (Romney and Gill, 2000); digestibility (Jones and Theodorou, 2000; Rymer, 2000; Tilley and Terry, 1963) and growth (Tamminga and Chen, 2000); rumen fermentation (Niwińska, 2009; Ørskov, 2000; Ørskov et al., 1980), and hematological profile of the animals (Harvey, 2006). When the feed is a non-conventional, which is not common in the diets of livestock, examination of its effect on rumen pH and level of blood constituents is important.

Ficus sur fruits (FSF) belongs to the genus *Ficus* that comprises about 750 species, with about 100 species in Africa, 500 species in tropical Asia and Australia, and 150 species in tropical America (Lumbile & Mogotsi, 2008). The species in Ethiopia is named as *Ficus sur* (Cv. Forssk.) or commonly named as fig. It is widely distributed in almost all National Regional States of the country. In Ethiopia, the FSFs have been traditionally used as food and feed for centuries by man and livestock, respectively, in different parts of the country. During dry seasons of severe feed shortage where crop residues and aftermath are the main feed sources for livestock, the ripen fruits drop from the trees by wind and all classes of livestock freely access with no restriction. During this time, FSF become important natural concentrate supplements for livestock and many lambs and kids grow fast and reach market weight in few weeks.

Though small ruminants like sheep usually consume FSF in many parts of Ethiopia, its impact on their rumen ammonia, pH concentration, and blood profile was not yet studied and no scientific information was available. Therefore, this study was conducted to evaluate the effect of ground

FSF mixed with ground oats grain (OG) diet on the rumen ammonia nitrogen, rumen pH concentration, and blood profile of Hararghe highland sheep.

Materials and Methods

Study site

The feeding trial on the sheep was conducted in Haramaya University sheep farm, which is located at 9^{o} 26'N latitude and 42^{o}3'E longitude in eastern Ethiopia. The altitude of the area is about 1980 meters above sea levels and the mean annual rainfall is about 910 mm with a range of 560-1260 mm. The mean maximum and minimum temperatures are 23.4^{o}C and 8.25^{o}C, respectively (summarized report from Haramaya University Meteorological Station, 2012).

Management of the experimental animals

Intact male yearling lambs with average initial live weight of 13.62 kg were purchased from Kulubi local market. The animals were carefully transported on lorry to Haramaya University and quarantined for 3-weeks. During quarantine period, they were sprayed with accaricides (*diazinone*) to control ticks; treated with *ivermectin* injection against internal and some external parasites, and penistrep against Pneumonia disease. The animals were ear-tagged for ease of identification. Then they were assigned to individual pen arranged in a block based on the animals ' initial live weight. The animals were handled with great care that assured their welfare until the end of the experiment.

Experimental diets and feeding management

Naturally ripen and dry FSF were collected from fig trees in Horro district, packed in clean sacks and taken to Haramaya University sheep farm. The fruits were further sun dried for three to four days depending on the weather condition (sunny or cloudy) to ensure grinding of the feed in conventional flour mill. The OG was purchased from Sheno town of North Shoa zone of Oromia National Regional State, ground in similar mill with the same particle size and taken to the sheep farm where FSF were stored. These two feeds (FSF and OG) were used as energy supplement being mixed at different proportions while noug seed cake (NSC) was given to all experimental animals as isonitrogenous protein supplement. Medium quality natural pasture hay, basal diet, was offered to the animals *ad libitum* at a refusal rate of 20%. Sheep were adapted to the treatment diets for two weeks. After completion of adaptation period, they were offered measured quantity of dietary treatments twice a day at 8:00pm and 16:00am in equal proportion. Lambs in each block were randomly assigned to one of the five diets. The animals were housed in individual pens furnished with feeder and watering bucket. Clean tap water was provided to the animals and it was changed whenever it is contaminated with feces or other material not appealing to the animal. The amount of supplement and basal diet offered and refused was measured and recorded every day before the next day's feed. The basal diet, natural pasture hay, was adjusted every 3-days to ensure 20% refusal. The live weight change of the animals was recorded every fortnight.

Dietary treatments and experimental design

The dietary treatments used in the experiments are *ad libitum* natural pasture hay (control); 100% *Ficus sur* fruits (FSF) and 0% oat grain (OG), which was represented as [100FSF]; 67%FSF:33%OG [67FSF]; 33%FSF:67%OG [33FSF]; 0%FSF:0FSF [0FSF]. Noug seed cake (NSC) was given to all animals with the purpose to fulfill at least the protein maintenance requirement of the control animal (at isonitrogenous level). The experiment was laid out in a randomized complete block design (RCBD) with five treatments and 6 replications each. The animals were grouped into six blocks based on their initial body weight and the five treatment diets were randomly distributed to the animals within each block.

Table 1: Treatment diets (ingredients) proportions (*ad libitum* natural pasture hay) on DM basis*

	Dietary proportions (DM basis)				
Ingredients (g)	Control	100FSF	67FSF	33FSF	0FSF
Ficus sur fruits	0	300	201	99	0
Oats grain	0	0	99	201	300
Noug seed cake	225	210	190	170	150
Nutrient composition of diets (%)					
Dry matter	91.8	91.4	91.4	91.4	91.4
Ash	9.3	8.1	7.3	6.9	5.6
Crude protein	15.4	15.4	15.4	15.4	15.4
Neutral detergent fiber	58.3	33.7	35.2	36.8	38.6
Acid detergent fiber	41.1	22.6	23.1	23.7	24.3
Hemicelluloses	17.1	11.1	12.0	13.1	14.3
Cellulose	33.6	17.2	17.7	18.3	18.8
Acid detergent lignin	7.6	5.4	5.4	5.5	5.5
ME calculated (MJ/kg DM)	8.6	10.4	10.2	9.9	9.6

FSF= *Ficus sur* fruits; ME= metabolizable energy; DM= dry matter *Natural pasture hay was offered *ad libitum* whereas noug seed cake was given to make the diets of all animals isonitrogenous. Control= *ad libitum* natural pasture hay supplemented with noug cake; 100FSF = 100% FSF with 0% oats grain; 67FSF= 67% FSF with 33% oats grain; 33FSF= 33% FSF with 67% oats grain; 0FSF= 0% FSF with 100% oats grain

Laboratory analysis of experimental diets

The laboratory analysis of the experimental diets was performed in Haramaya University Animal Nutrition laboratory. The feed samples were taken each day and pooled over the experimental period in separate bag. At the end of the feeding trial, the bulked feed was thoroughly mixed and ample sample was taken for dry matter determination and chemical analysis.

After the samples were partially dried in forced draft oven at 65^{o}C for 48 hours, it was ground to pass 1mm Wiley mill sieve size put in crucible and labeled. The chemical analysis for each sample was run in duplicates. When the results of the two replicates were not similar, the mean result was taken provided that the result of the two replicates did not vary by more than 5%.
The DM and ash contents of the feed samples were determined following the procedure of AOAC (1995). The NDF, ADF, and ADL were determined based on the method described by Vansoest and Robertson (1985). Hemicelluloses and cellulose were calculated as NDF-ADF and ADF-(ADL+ADF ash), respectively. The ME (MJ/kg) of the diets was estimated according to Moran (2005). The N content of the samples was determined by the micro-Kjeldahl method and CP was calculated as N X 6.25.

Rumen fluid collection and analysis

The sample for rumen fluid was taken after the animals consumed the treatment diets for 90 days/period. Four animals from each treatment were randomly taken for collection of rumen liquor. About 30-40ml of rumen fluid was collected using stomach tube at 4 hours post feeding. The pH reading at 0, 2, 4, 8, 12, and 24 hours was taken immediately after the fluid was withdrawn from the rumen using Demetra model PM 53D portable pH meter. The rumen fluid was strained through double layers of cheesecloth and transferred into clean plastic bottles containing 10 ml sulfuric acid and stored in deep freeze at -20^{o}C until used for rumen ammonia nitrogen analysis following the Kjeldahl procedure (ILRI, 1997).

Blood count, PCV determination, and sera biochemical analysis

Before taking about 10 ml of blood sample from jugular vein of the sheep, the animals were fasted for eight hours (Theml et al., 2004). Heparinized vacutainer tube was used to collect blood to prevent coagulation during sample collection. Half of the blood was used for the determination of RBC and WBC according to the Neubauer counting chamber (Jain, 1986; Bassert and McCurnin, 1985) and hemoglobin concentration according to Harvey (2001). Smears for differential leucocyte counts were stained by the Leishman technique, and the different cells of leucocyte series were enumerated by the longitudinal counting method. The other half of the blood was used to determine packed cell volume (PCV) and serum nutrient compositions. For PCV determination, four disposable capillary tubes of about 75mm length and

1.07-1.24 mm diameter was used to fill with about 50µm blood samples (WHO, 2000). After filling the samples a pliable sealing compound was used to close one end of the tube to prevent blood flow. A microhaematocrit centrifuge with 8cm radius was used to agitate the specimen in capillary tubes at 10,000 rpm for 5 minute. Then the PCV was read against PCV tube reader, model AIC 1490 and recorded. After blood for PCV determination was taken, the remaining blood was centrifuged in RCF K40R centrifuge to separate the plasma, which was then collected into separate plain tube and sealed and stored in deep freeze at a temperature of –20°C until it was used for analysis of urea by the urease–Berthelot method (Coles, 1986), glucose by Folin and Wu approach (Ullman et al., 1992), creatinine according to Henry (1974), globulin and cholesterol by spectrophotometer (Braham and Trinder, 1972; Merck, 1974; Doumas et al., 1981) and total protein concentrations according to Merck (1974) and Doumas et al. (1981).

Statistical analysis

The experiment was laid out in a randomized complete block design (RCBD) with 5 treatments and 6 replications each. Initial body weight of the animals was used for blocking and animals with similar body weight were grouped together. The animals were randomly allocated to treatments independent of the block. The data collected on rumen ammonia, rumen liquor pH, blood counts, and serum metabolites were analyzed by General Linear Model (GLM) procedure of Statistical Analysis System, SAS (2008). When F-test declared the existence of significance, means were compared using Tukey honestly significant difference test at P<0.05. The model, $y_{ijk}=\mu + \tau_i + \beta_j + \varepsilon_{ijk}$, where, μ=overall mean of the population, τ_i= The ith treatment effect, β_j= The jth block effect, and ε_{ijk}=random error associated with y_{ij}, was used for data analysis.

Results

Chemical composition of experimental diets

The chemical constituents of the experimental diets are presented in Table 1. The DM content of the experimental diets was similar. The 100FSF diet had higher Ash and calculated ME compared to 0FSF. The fiber constituents were higher in 100FSF than 0FSF.

Rumen ammonia nitrogen and pH concentration

Table 2 shows rumen liquor pH concentration and ammonia nitrogen (NH_3-N) profile. The animals fed with the control diet (diet with no FSF or OF) had highest (P<0.001) pH concentration compared to the rest of the treatment diets followed by the group supplemented with sole OG, which is higher than those supplemented with sole FSF. The pH observed for all treatment is a little above neutral, tending to be slightly alkaline (7.34). The NH_3-N content of the rumen fluid was not significantly differed (P>0.05) between the treatments and it is higher in magnitude in treatments supplemented with sole OG or combination of OG and FSF as compared to the control and Sole FSF fed group. The pH slightly increased during the first two hours and declined thereafter, until it stabilizes at about eight hours in all treatments (Fig 1).

Table 2: Rumen pH concentration and NH_3-N profile of sheep supplemented with mixture of FSF and OG at different proportions (samples collected at 4 hours post feeding)

Rumen Parameters	Treatments						
	control	100FSF	67FSF	33FSF	0FSF	SEM	SL
Rumen pH	7.34[a]	7.12[c]	7.14[bc]	7.19[bc]	7.24[b]	0.022	***
NH3-N (mg/l)	84.6	84.7	85.3	85.5	85.7	0.441	Ns

FSF= Ficus sur fruits; NH_3N =Ammonia Nitrogen; 100FSF =100% FSF: 0%OG, 67FSF =67%FSF:33%OG; 33FSF =33%FSF:67%OG; 0FSF = 0%FSF:100%OG; SEM= Standard error of the mean; SL= significance level; ns= non-significant.

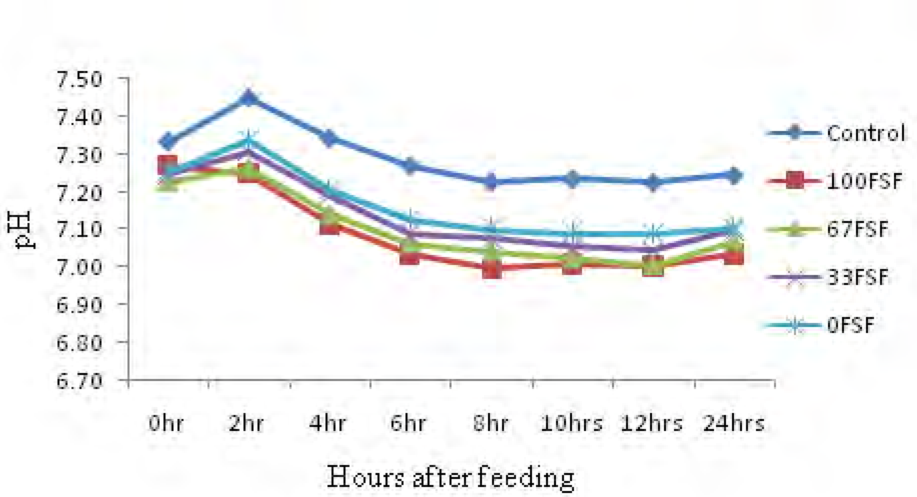

Fig 1: Effect of dietary treatments on rumen pH concentration dynamics of the sheep

Blood count

The analysis of variance indicated that white blood cell (WBC) did not statistically differ between treatments (P>0.05) (Table 3). Generally there was no clear trend in WBC count, being slightly higher in magnitude for the group fed the control diet. Red blood cell count is different among the treatments (P<0.001) and it is higher in 33FSF:67OG ratio than the group supplemented with either sole FSF or OG and 67FSF:33OG. Values for Hgb, MCV, and MCHC did not differ significantly (P>0.05) among treatments and there was no any trend in magnitude of the values. However, MCH is significantly higher in sole oat grain supplemented group than 33OG:67FSF and the control diet groups.

Table 3: Blood counts of sheep fed different proportions of ground *Ficus sur* fruit and oat grain mixture

	Dietary treatments						
Blood parameters	control	100FSF	67FSF	33FSF	0FSF	SEM	SL
WBC (10^3/µl)	12.8	11.5	11. 7	12.7	12.7	0.542	ns
RBC (10^6/µl)	13.2[ab]	11.5[bc]	12.0[bc]	14.7[a]	11.0[c]	0.402	***
Hgb (g/dl)	12.2	13.3	12.5	12.2	11.8	0.745	ns
PCV (%)	32.3	38.5	40.8	38.2	36.7	2.045	ns
MCV (fL)	24.5	33.5	34.0	26.0	33.4	2.708	ns
MCH (pg)	9.26 [bc]	11.7[ab]	10.4[abc]	8.33[c]	12.6[a]	0.069	**
MCHC (g/dl)	38.3	35.1	31.1	32.3	38.4	2.888	ns

FSF= Ficus sur fruits; *SEM* =Standard error of the mean; *SL*= significance level; *ns*= non-significant; *WBC* =white blood cells; *RBC*=red blood cells; *Hgb*= Hemoglobin; *PCV*= packed cell volume; *MCV*= mean corpuscular hemoglobin; *MCHC* =mean corpuscular hemoglobin concentration; 100FSF =100% FSF: 0%OG; 67FSF =67%FSF:33%OG, 33FSF = 33%FSF:67%OG; 0FSF = 0%FSF:100%OG;

Sera metabolites

The blood serum metabolites for the experimental animals as affected by varied proportions of ground Fig and MG mixed diets was presented in Table 4. There was no significant difference (P>0.05) between the treatments in sera metabolites.

Table 4: Blood serum metabolites of sheep fed different proportions of ground *Ficus sur* fruit and oat grain mixture

	Dietary treatments						
Serum metabolites	control	100FSF	67FSF	33FSF	0FSF	SEM	SL
Urea (mg/dl)	27.8	28.9	28.8	29.4	33.2	1.621	Ns
Creatinine (mg/dl)	1.29	1.33	1.37	1.37	1.38	0.032	Ns
Cholesterol (mg/dl)	58.3	55.2	59.8	62.7	59.8	2.915	Ns
Glucose (mg/dl)	59.0	61.0	63.5	59.7	61.3	2.419	Ns
Total protein (g/dl)	6.68	7.22	7.12	7.18	7.33	0.234	Ns
Albumin (g/dl)	3.65	3.95	3.77	3.83	3.77	0.111	Ns
Globulin (g/dl)	3.03	3.27	3.34	3.35	3.57	0.164	Ns
Albumin:Globulin	1.22	1.24	1.13	1.15	1.06	0.057	Ns

FSF= Ficus sur fruits; *SEM* =Standard error of the mean; *ns*= non-significant; *SL*= significance level; 100FSF =100% FSF: 0%OG; 67FSF =67%FSF:33%OG; 33FSF= 33%FSF:67%OG; 0FSF=0%FSF:100%OG.

Discussion

Chemical composition of experimental diets

All the four types of diets had almost similar values for DM. The OM content of the feeds was more influenced by its ash content. The higher ash content (7.15%) of FSF resulted in its' relatively less OM content as compared to OG (3.7%). Nevertheless, the higher OM contained in OG does not necessarily mean higher availability of the nutrients to the animals. This is because the higher ADF composition in OG than in FSF can presumably reduce its digestibility (McDonald et al., 2002). Moreover, the higher NDF value in OG may influence voluntary feed intake and provide less nutrients for the proliferation of rumen microbes compared to FSF. This is because FSF has higher neutral detergent soluble fiber than OG that can support rumen microbes as sources of soluble carbon. In this regard, FSF could be important energy supplement than OG. This in turn influences the digestibility of the fibrous basal diet utilization. Moreover, the variations in nutrient composition and types of the diets may influence hematological profile of sheep (Abdollahzadeh and Abdulkarimi, 2012; Schaefer et al., 2009).

Rumen pH and ammonia nitrogen concentration

The highest pH concentration in control diets compared to the rest treatment diets may suggest that animals fed the control diet did not receive sufficient energy concentrate as readily soluble carbon supplements, since this group received only noug seed cake, which served as nitrogen source and is slightly alkaline in nature. This was not preferable for better microbial ecology (Owen and Goetsch, 1988). As a result, the rumen microbes may be less active and small proportion of the basal diet (natural pasture hay) might have been degraded to yield volatile fatty acids (VFA), which could have diluted the alkaline nature of ammonia released from protein supplement in the control diets (Bodine et al., 2000; Carey et al., 1993). The relatively lower pH values of rumen liquor in sheep consumed 100FSF was due to higher proportion of energy concentrate supplement, which contained less fiber portion compared to OG in 0FSF diet. The pH concentration in rumen of the sheep consumed 100FSF was nearly neutral, which is considered as important since it is conducive especially for fiber fermenting (cellulolytic) microorganisms (Owen and Goetsch, 1988). Relatively lower, but nearly neutral values (6.9-7.1) pH were reported by other researchers (Yoseph et al., 2003) for Menz sheep fed with natural pasture hay basal diet supplemented with different conventional protein sources, such as *T. atella* (traditional brewery residue), lentil hulls (*L. culinaris*), *K. atella* (traditional liquor residue), rough pea hulls (*L. sativa*) and field pea hulls (*P. sativum*). Baraka and Abdl-Rahman (2012) reported lower figures (6.4-6.6) than the current finding for sheep fed barley grain energy supplement to hay basal diet.

The nearly similar values of NH_3-N were probably due to the isonitrogenous levels of treatment diets fed to all sheep. The level of ammonia for all treatments in the present study was above the minimum level (50 mg/l) required to maximize microbial growth (Krebs et al., 2007) but lower than the amount (86.7-117.3 mg/l) reported by Baraka and Abdl-Rahman (2012) under *in vitro* evaluation of sheep rumen fermentation pattern. No sheep in the present study showed symptom of ammonia toxicity such as difficult breathing, rapid pulse, salvation, bloat, tremors, in coordination, staggering, and tetany (Nauhaus, 2008; Robson, 2007) indicating healthy conditions of the experimental diet. This might be due to reduction of the rumen fluid pH concentration from 2 hours to about 8hours post feeding (Nikkhah, 2011) after which it attained more or less stable trend for all treatments until 24 hours (Fig. 1) at nearly neutral reactions. The rise in pH concentration at early phase of degradation (from 0 to 2 hours), except in group supplemented with sole FSF, may be attributed to faster degradation of the protein supplement than the relatively longer lag phase (Ørskov et al., 1980) for fibrous natural pasture hay basal diet, which resulted in volatile fatty acids that might have reduced the pH during that phase. Rapid reduction in pH in group supplemented with sole FSF is attributed to the availability of soluble carbon to the microbes from the diet for ease of fiber fermentation.

Blood count

The values for WBC were all in the normal range (11-22*10^3/µl) documented in literature (Radostits et al., 2006; Jackson and Cockcroft, 2002; Scott et al., 2006). White blood cell count above 22*.10^3/µl is known to be an indication of infection in sheep (Radostits et al., 2006). This indicates that the immunity of the animal is not affected by any of the supplement used in the present experiment.

The RBC counts in the present study was higher than the values 6.35-7.65*10^6/µl reported by Abdel et al. (2011) for sheep consumed Ca-Saponified Lemuru Oil Coated by Herbs and the 9.1-10.7*10^6/µl reported by Astuti and Sudarman (2009) for urea treated or untreated groundnut hull supplemented with different protein source diets. Nevertheless, it was still in the normal range of RBC counts in healthy sheep 9-15*10^6/µl as documented by Jackson and Cockcroft (2007) indicating absence of any infection in the animal.

The overall Hgb concentration in this study (12.2-13.8 g/dl) was within the normal range (9-15 g/dl) described by Radostits et al. (2006) and Jackson and Cockcroft (2007), but less than the range (41.02-45.43g/dl) obtained by Addass et al. (2010) for different sheep breeds from different husbandry background. In contrary to the former report, Islam et al. (2005) obtained lower Hgb values (8.36-10.0 g/dl) for yearling sheep fed with diets containing different types of hematinics which improved the health of the animals. Hence, none of the experimental units fed with different experimental diets were suspected for anemia or parasitic case (Teleb et al., 2007) in the present study.

Compared to the present finding, relatively lower PCV values of 26.4 - 35.2% were obtained by Al-Saad et al. (2007) from their study on natural zinc deficiency in sheep with different age and sex. The authors reported that those sheep with PCV values of 26.4-28.4% were considered diseased. There was a controversy in literature in the value of PCV. Radostits et al. (2006) noted that PCV of 27% is the normal minimum value for sheep. The PCV value of an animal is affected by different factors, and lower PCV indicates that body has fewer red blood cells than normal. These include chronic kidney diseases, blood loss from hemodialysis, abnormally low levels of iron, vitamin B12, folic acid, species and age of animals (Egbe-Nwiyi et al., 2000). According to this, the PCV value obtained in the present experiment may be an optimum value and indicates no loss of blood and anemic case symptoms is occurred to the animals.

The mean cell volume (MCV) obtained for some of the treatments in the current study is somewhat lower compared to other findings (Radostits et al., 2006; Jackson and Cockcroft, 2007) who suggested 28-45 fl levels as normal value for sheep. Rise in MCV above 45 fl indicates liver and thyroid problems and deficiency of vitamin B12 and folate, and anaemia (Cox, 2009). Values lower than 28 fl shows existence of parasites, iron anemia, vitamin C deficiency, cobalt deficiency, low hydrochloric acid in their abomasums, rheumatoid arthritis, or lead toxicity (Hala et al., 2008; Saad and El_Sayed, 2014).

In both cases, the MCV value in the present study was free of hematological disorders, which were not observed in any of the experimental units in the present study. The MCH and MCHC are all in the optimum sera metabolites range (Radostits et al., 2006; Jackson and Cockcroft, 2007) recommended for different breeds of sheep at various husbandry conditions and no chronic hematological cases was observed.

Sera metabolites

Serum urea level is an indication of kidney function in lambs. The absence of significant variation in serum urea concentration among treatments was mainly due to equal level of dietary protein supplements. The least serum urea concentration in magnitude was recorded for sheep consumed control diets (natural pasture hay basal diet with noug seed cake protein supplement) while the highest was for those fed with 0FSF (100% OG). The reason for this was not clear yet. Similar range of results (19.5 mg/dl – 31.8 mg/dl) with the present study was reported by AL-Zghoul et al. (2008) for Awasi lambs kept in a closed farm and fed a regular fattening ration. The sera urea level in the present finding was in the range for normal renal physiology (17.12– 42.8mg/dl) as documented by other researchers (Radostits et al., 2006). It can be considered that the kidney of all the experimental sheep is normal as far as the impact of sera urea concentration was concerned.

Creatinine level is an indicator of renal health status in animals. Some researchers (Zamiri and Rezaei-Roodbari, 2004) found a slightly lower creatinine concentration (1.02mg/dl to 1.13 mg/dl) for sheep consumed 50% alfalfa hay with 50% barley grain diets compared to the present study and no kidney problem was reported. In contrary to this, previous studies indicated that dehydration for two to six days in sheep kept on normal diets increased serum creatinine from 1.6 mg/dl to 4.9 mg/dl indicating some degree of muscle damage (Kataria and Kataria, 2007). Since increased level of creatinine is indicator of chronic renal dysfunction (Fartashvand et al., 2012), the concentration level found for sheep supplemented with the new feed resource, 100% FSF (1.33mg/dl) can be considered as the safest value.

The normal blood cholesterol concentration range 43-103 mg/dl in sheep of different age and breeds (Radostits et al., 2006). Different earlier reports confirmed the present finding (52-76 mg/dl, Landgraf et al., 1984); (53.7 – 64.1 mg/dl, Hatfield et al., 1998); (34.65-38.1 mg/dl, Khadem et al., 2007). However, Zamir and Rezaei-Roodbari, (2004) reported the lowest result (33.1- 40.63 mg/dl) for rams consumed alfalfa hay supplemented with barley grains. The Hararghe highland sheep used in the present study, therefore, had normal serum cholesterol level and one may not suspect any cardiac infarction or heart attack diseases (McDonald et al., 2002) that usually occurs in cases when the blood cholesterol rises beyond the normal level as a result of inclusion of mainly excess saturated fatty acids in their diets.

The sera total protein concentration for all treatments in the present study was similar, except for the control group. This could be an attribute of lack of soluble carbon as energy supplement in the diets of sheep received control diets. Soluble carbon supports optimum proliferation of rumen microbes, which ultimately contribute to microbial protein, which could be digested in the subsequent gastro intestinal tract and absorbed into blood system and increase blood protein concentration. The albumin, globulin, and their ratios (Albumin: Globulin) were all in the normal ranges (Jackson and Cockcroft, 2007) that indicated absence of parasitism, hepatic diseases, protein deficiency, starvation and malignancy. The result obtained rather indicates optimum proteinacious feed intake (Keser and Bilal T., 2008) and secured immune status.

Conclusion

The present study indicated that feeding *Ficus sur* fruits to the lambs could result in nearly neutral rumen liquor pH, optimum rumen NH_3-N concentration and normal count of WBC, RBC with optimum levels of PCV, Hgb and sera metabolites, which all indicated healthy rumen and cardiovascular physiology. Hence, the FSF can be used as sole supplement or as a replacement for OG as energy source where accessibility and cost of OG is a limiting factor, particularly in small holder sheep production system.

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