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THESIS

ASSESSMENT OF FEEDING SYSTEMS AND EVALUATITION OF FEED SUPPLEMENTATION ON BODY WEIGHT AND FLEECE PRODUCTION OF SHEEP IN ETHIOPIA

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A survey was conducted in ten districts of the central and north western parts of Ethiopia to assess the production system, feed resources and to determine the chemical and mineral composition of the feeds. The results revealed that about 40% of the farm income is generated from the sale of live animals or animal by-products. Sheep play a great role in settling of any outstanding debts; and sheep fattening takes 3 to 6 months which mainly targets holidays. To overcome the over utilization of communal grazing lands, the community suggested the use of improved animal breeds and lower stocking rates (70%), followed by developing of cultivated forage crops (15%). The major constraints of animal production in the surveyed districts according to the respondents were scarcity of feed, prevalence of disease, lack of proper marketing channel and inadequate extension and credit services. Among the feed types collected and evaluated for their chemical and macro mineral contents; by-products (flour and oil crushing meals), cultivated forage crops and straws of food legume contained high CP than any other feed types. CP was found to be the most limiting nutrients in which 47.73% of the feeds were found to be deficient. By-products of *G. abyssinica* and *Brassica spp* were found to contain the highest amount of CP (35.85). About 78, 11 and 32% of the feeds were found to be deficient in Na, P and Mg, respectively, while Ca was found to be sufficient in 95.45% of the feeds. Most of the feeds evaluated were found to be insufficient in proteins and minerals. Hence improvement methods that could be adopted by the farming community should be developed for maximum utilization of the feeds.

Three feeding trials were conducted at Debre Berhan Research Center, Ethiopia to quantify the effect of lotus hay, complete mineral block and barley straws and natural hay pasture supplementation on sheep growth and fiber production of three sheep of the central high lands (Awassi×Menz, Menz and Tukur). In the first experiment four levels of *L. corinuclatus* hay (0, 100, 200 and 400) were evaluated in three sheep breeds. Supplementation of 200 g lotus per head per day on top of the 8 hours grazing was found to bring about weight gains higher ($p<0.0001$) than the lower levels and equivalent to that of the 400 gram per head per day level ($p>0.05$). However, supplementation of lotus did not produce any significant effect ($p>0.05$) in any of the fiber characteristics. Awassi×Menz lambs produced a greasy fleece of 1037.98 g, clean fleece of 573.0 g, and fiber length of 11. 5 cm and a diameter of 61.79 µm which are significantly different ($p<0.01$) from those of Menz and Tukur sheep breeds. In the second experiment the effects of mineral supplementation on body weight, carcass and fiber characteristics were evaluated using the three sheep breeds in a 2x3 factorial arrangement. Supplementation of minerals did not produce a significant variation ($p>0.05$) in final weight, average daily weight gain and dressing percentages. No variation was also noted ($p>0.05$) in any of the measured fiber characteristics. In the third experiment the potential of native pasture hay and barley straws as supplement for sheep grazing natural pasture was evaluated. Native pasture hay and barley residue with a CP content of 5.98 and 2.96% did not produce any impact on final weight, average daily weight gain and dressing percentage. Supplementation with barley straws and hay produced 550.48 and 694.08 g greasy fleece respectively as compared the 818.22 g for the un-supplemented group. The difference among the three treatments was not significant ($p>0.05$) and there was no interaction between the main effects (the feed and the breeds).

Student's signature

Pornsri Chairatanayuth 02 / 08 / 06

Thesis Advisor's signature

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Aschalew Tsegahun
July, 2006

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LIST OF ABBREVIATIONS

ADF	acid detergent fiber
ADG	average daily gain
ARC & ECA	Amhara Regional Council &Economic Commission for Africa
asl	above sea level
A×M	Awassi × Menz
Ca	calcium
CEC	cation exchange capacity
Co	cobalt
cm	centimeter
CSA	Central Statistics Authority
CT	condensed tannins
Cu	copper
dl	deciliter
DM	dry matter
EARO	Ethiopian Agricultural Research Organization
FAO	Food and Agricultural Organization
Fe	iron
g	gram
ha	hectare
Hb	hemoglobin
I	iodine
ILCA	International Livestock Research Center for Africa
ILRI	International Livestock Research Institute
K	potassium
kg	kilogram
OC	organic carbon
OM	organic matter
m	meter
Mg	magnesium

LIST OF ABBREVATIONS (Cont'd)

mm	millimeter
Mn	manganese
Na	sodium
NaCl	sodium chloride
NDF	neutral detergent fiber
P	phosphorus
PA	plasma albumin
PCV	packed cell volume
SARC	Sheno Agricultural Research Center
SAS	Statistical Analysis System
Se	selenium
SE	standard error
TP	total protein
Zn	zinc
^oC	degree centigrade
>	greater than
<	less than
µm	micrometer
%	percent

ASSESSMENT OF FEEDING SYSTEMS AND EVALUATION OF FEED SUPPLEMENTATION ON BODY WEIGHT AND FLEECE PERDUCTION OF SHEEP IN ETHIOPIA

INTRODUCTION

Ethiopia, with a total area of 1.2 million km^2, is an agricultural country located at 3 to 15 ^{o}N latitude and 33 to 48 ^{o}E longitude. It is endowed with a population of 30 million cattle and 40 million small ruminants (ILRI, 2000). Due to the impact of different constraints including inadequate health service, poor nutrition, uncontrolled breeding and poor marketing systems, the level of productivity and revenues derived from the livestock sector are not satisfactory (Tembley, 1998; Degefe and Nega, 2000; Desta, *et al*., 2000). Livestock production in the country is not market-oriented and animals are considered as an integral part of the mixed farming system, kept mainly for the supply of agricultural power, source of food, and means of saving and social prestige. Owing to the low average productivity level, the share of livestock production to the gross domestic product (GDP) is very low and is 15-17% (Negussie, 1987; Mekonen *et al*., 1991). This fact is manifested by making comparisons with the neighboring countries. The annual per capita mutton production in Ethiopia is 9.9 kg per head, while the mutton production in Kenya and the Sudan is 12.2 and 16 kg, respectively (ILRI, 2000).

Feed availability, in terms of both amount and quality, is considered as the main bottleneck of the sub sector. Animals are forced to thrive on grazing pasture, crop residues, and hay throughout the year with little or no supplementation. In addition to the seasonal and altitudinal variation, available feeds from grazing and crop residues are nutritionally inadequate (Keogham, 1980; Jutzi *et al*., 1987; Kabaja and Little, 1988). Amhara Regional state, which owns about 35% of the nation’s total livestock population, is not different from the other parts of the country (BoA, 1999a).

Grazing fields are overstocked nine times more than their carrying capacity (ARC and ECA, 1996), resulting in pastureland deterioration. The role of cultivated pasture to rectify the problem is none as plots covered with improved forages are insignificant. The traditional livestock production system does not appreciate the seasonal pattern of demand and supply to cope with the problem, and results in lower output, which is more noticeable in the dry season. In this, particular period farmers used to feed straws and hay as additional feed to overcome the shortage.

In the mixed farming system, crop residues integrate crops and livestock where the high human population growth pressurizes the production of grain crops and animal feeds from the same plots of lands. Shiferaw (1991) estimates a decrease of 0.32 ha of grazing land for every newly born child. The use of concentrates by smallholder farmers to avert the situation is not encouraging due to escalating prices (Silishi and Bediye, 1991). Yami *et al*. (1991) suggested that the use of home grown and conserved feeds to alleviate the problem as these feeds produced at home with a relatively low cost.

Sheep are reared mainly for their ease of liquidation, besides their contribution in the supply of mutton, fleece, and manure (Alemayehu and Fletcher, 1993). Sheep population per household in the region varies based on altitudes, and increased with a rise in elevation. In higher altitude regions, where the Menz and the Tukur sheep are the dominant breeds, farmers shear their flocks at least once a year. Shearing is done for sanitary reasons and in areas where the fleece is used for weaving carpets, wall hanging, hats, and other covering materials for its economic value (Galal, 1982). Although many of the region's inhabitants in one way or another depends on sheep and their products, no figures are available with regard to the potential of fiber production from different breeds of sheep with possible feed supplementation.

Before initiating any intervention in the current livestock production system, it is imperative to quantify the existing scenario and properly document the available information (production system and feed resource base) in order to understand its impact on animal productivity and income of the smallholder farmers.

Objectives

This study was therefore initiated with the following main objectives.

1) To assess the available feed resources and list out the major constraints of sheep production.

2) To determine the chemical and mineral composition of the major feeds used by the farming community.

3) To quantify the effect of barley straws and natural pasture hay, forage legume hay (*Lotus corniculatus*), and complete mineral supplementation on sheep growth and fiber production of three sheep breeds (Awassi×Menz, Menz, and Tukur) in the central highlands of Ethiopia.

LITERATURE REVIEW

General Description of the Area Physical Feature

The Amhara Region is one of the nine administrative regions of the country located between the coordinates of 8^o 45’ N to 13^o 45’ N latitude and 35^o 46’ E to 40^o 25’ E longitude. With a total area of 170,752 km^2 (which is one-eighth of the country’s area), it owns about 27 percent of the human (Degefe and Nega, 2000) and 35 percent of the livestock population of the country (BoA, 1999a). Of the total surface area of the region 33.8 percent is classified as arable land while grazing and browsing area constitutes 44.7 percent, and natural vegetation accounts for 5 percent (ARC and ECA, 1996). The region encompasses the largest inland lake (Tana) and the highest mountain peaks (Mount Dashen, 4620 m above sea level). Generally, the region is divided into three climatically distinct ranges based on altitude. The high altitude areas, which are above 2300 m above sea level and locally termed as “*Dega*” constitute 25 percent. The mid altitude areas between 1,500–2,300 m above sea level locally known as “*Woina Dega*” cover 44 percent and the low altitude areas below 1500 m above sea level (“*Kolla*” locally) constitute 31 percent of the total area of the region (ARC and ECA, 1996). The wool bearing sheep are reared in areas above 1500 m, where the temperature is mild and cool with reliable rainfall and no risk of trypanosomes (Benin *et al.,* 2002).

The diverse agro-ecology of the region favors for the existence of various animal species and it is not uncommon to see more than one species of animals per household. The region supports 10.51 million cattle, 5.32 million sheep, 3.82 million goats, 0.30 million horses, 1.47 million asses, 0.11million mules, 0.03 million camels and 13.43 million chickens (Table 1). The distribution, density and importance of the species vary from zone to zone and district to district (Gebrewold, 1987; BoA, 1999a). This is mainly attributed to the availability of feeds, prevalence of diseases and the farming system in use. Large numbers of cattle are found in north Gonder and south Wello, while higher concentrations of sheep are found in south Wello and north Shoa.

Table 1 Livestock population of the Amhara Region by administrative zones.

Administrative zone	Livestock type							
	Cattle	Sheep	Goats	Horses	Asses	Mules	Camels	Poultry
North Gonder	1,936,543	52,4087	682,264	38,236	223,116	12,474	792	3,165,069
South Gonder	1,182,912	48,6212	43,8975	23,269	171,041	12,832	2,728	1,575,937
North Wello	910,763	61,0341	429,284	32,027	141,934	10,600	6,233	1,200,512
South Wello	1,469,751	1,489,247	72,0544	48,484	252,841	27,426	3,274	1,933,730
North Shoa	1,021,040	888,095	51,7431	33,085	238,716	11,009	3,170	1,333,835
East Gojjam	1,263,726	591,329	215,761	50,633	178,838	9,199	905	809,702
West Gojjam	1,399,492	372,879	181,795	19,366	148,180	12,054	4,811	2,016,039
Wag Hamra	35,5055	86,328	417,737	-	42,970	4,154	-	252,657
Awi	638,869	248,566	91,959	61,074	39,419	4,479	830	81,044
Oromia	326,825	20,969	119,590	-	27,737	977	5,685	308,890
Bahidar	7,801	2,277	518	-	228	309	-	28,363
Total	10,512,777	5,320,330	3,815,859	306,443	1,465,021	105,514	28,475	13,434,878

Source: CSA (2003).

The livestock population of the surveyed districts is shown in Table 2. Accordingly 21.57% of the sheep population of the Region is found in the districts, indicating the favorable conditions of the districts and their economic importance to the livelihood of the farming community.

Table 2 Livestock population of the surveyed districts.

Districts	Livestock type							
	Cattle	Sheep	Goats	Horses	Asses	Mules	Camels	Poultry
Debark	71,014	47,853	39,072	10,809	10,095	875	-	161,911
Wegera	112,494	94,651	38,353	10,451	21,560	1,454	-	213,721
Farta	143,194	80,441	41,312	6,328	20,366	3,859	551	136,460
Lay Gayint	91,278	69,495	43,561	5,361	20,041	758	-	100,804
Meket	135,374	115,643	62,935	12,109	18,895	1,946	-	137,165
Wadla	77,132	111,990	23,150	12,410	9,043	1,593	-	74,785
Were Ilu	86,520	158,819	25,267	5,401	24,342	2,236	-	114,282
Tenta	100,573	166,253	57,712	8,080	20,542	2,313	-	113,268
Gera Keya	83,698	200,403	39,553	3,608	21,876	1,195	-	105,776
Lalo Midir	69,864	101,980	31,162	1,905	17,420	856	-	749,30
Total	971,141	1,147,528	402,077	76,462	184,180	17,085	551	1,233,102

Source: CSA (2003).

With regard to the climate, the mean temperature and annual precipitation of the Region varies from 7.5°C to 25°C, and 300 – 2,000 mm, respectively (BoA, 1999b). The main rainy season lasts from mid June to September, while the small rainy season commences in February and extends up to April, with the respective peaks of August and March.

The highlands, which support 70.8% of the human and 80% of the animal population of the country (Gryseels and Anderson, 1983; Kebede, 1987) is endowed with a diverse plant, animal and microbial genetic resources where, 64 legume species were reported to be endemic by Hanson and Mengistu (1991). However, in this part of the country land clearing, intensive cultivation, and land degradation and heavy grazing usually result in poor availability of feeds which in turn becomes a cause for poor animal performance. Benin *et al*. (2002) indicated that resource degradation increases with altitude as both human and livestock population increases, which affect the species composition and the feed base. Availability and type of natural pasture depend on the amount and distribution of rainfall, altitude, soil type, temperature, and the grazing pressure exerted on the pasture (Gebrehiwot and Tadesse, 1985). Natural grasslands contribute more than 79 percent of the feed either in the form of grazing or as grass conserved in the form of hay. The remaining 21 percent comes mainly from crop residues of cereals and pulses (MoA, 1984). The livestock production system heavily relies on grazing, fallow lands, and crop residues with no extra supplementation and minimum health care (Tembely, 1998). The inadequacy of feed results in poor performance of animals.

Crop and Animal Farming

Farmers keep animals to use them in farm operations and to generate income as well as for household consumption (Mekonen *et al*., 1991). In the highlands of Ethiopia where the undulant topography, high initial investment and running costs limit the use of machinery, increasing the number and improving the condition of stock means strengthening the ability to cultivate more land timely. Livestock have made it possible to utilize areas, which cannot be otherwise productive considering the current situation of the country.

Despite the huge livestock wealth and investment made over the years, livestock contribute only 15 - 17% of the total GDP (Nigussie, 1987; Mekonen *et al.*, 1991). Inadequate feed, poor breeding practices and prevalence of livestock diseases (Awgichew, 1987; Gebrehiwot, 1987; Gebrewold, 1987; Kebede, 1987; Tembely 1998) and inadequate livestock polices (Desta *et al.*, 2000) have been reported as the main constraints of livestock production in Ethiopia.

Cropping pressure in the extreme highlands is relatively low (Lemma *et al.*, 1998) and farmers possesses high sheep population, which provide a secure form of investment (Alemayehu and Fletcher, 1993). Sheep flock size varies from two to ten per hectare and increases from 10 to 30 at very cold higher elevation of above 3000 m (EARO, 2000). Farmers would like to keep sheep because of their prolificacy, rapid reproductive cycle, quick return, low feed requirement and ease of handling (Belay, 1998). Sheep and goats represent a liquid form of capital than cattle and are readily tradable to cover any additional costs (Alemayehu and Fletcher, 1991). Though capital invested represents 6.6 - 7.0%, the sales of small ruminants and their products generate 40 - 48% of the cash income of the farmers (Awgichew *et al.*, 1989; Alemayehu and Fletcher, 1993). However, the revenue generated from sheep and goats is very low as compared to the wealth that the country owns. This is mainly true because of the difficulty of implementing of any selection program due to small flock size per farm and uncontrolled breeding (Galal, 1982; Belay, 1988). As a result, the present sheep population of Ethiopia is the result of natural selection and management (Lemma *et al.*, 1998).

Animals that thrive in the region are well adapted to the scenario of the environments where they are bred and contribute much for the sustainability of the system. None of the animals was bred or selected for specific objective/s; farmers obtain various outputs from a single animal with minimum inputs. This is not exceptional to sheep; none of the farmers specializes in sheep husbandry. Sheep are kept as part and parcel of the mixed agricultural system and fleece harvesting and processing is taken as sideline work.

Awgichew (1987) reported that the indigenous sheep of Ethiopia fall into many types, whose habitat extends from tropical to cool temperate environments and they vary in size, coat color, tail shape and presence or absence of horns. Lemma (2002) classified sheep of the Amhara Region phenotypically into four major groups: the Central Highland sheep, the Rift Valley sheep, the North-western Highland sheep and the Western Lowland sheep. Among them, Menz, Wello and Tukur are sub types kept as a dual-purpose sheep (Awgichew *et al*., 1991).

Feed Availability and Management

Grazing areas have declined due to the expansion of crop cultivation and human population. Shiferaw (1991) reported that for every child born there is a decrease of 0.32 ha of grazing land. Increased number of animal population and the communal grazing land ownership system lead to range land deterioration (Nigussie, 1987). In the higher altitudes, grazing areas are overstocked more than nine times than it should be (ARC and ECA, 1996) which makes application of rotational system (Tembely, 1998) and any intervention towards the improvement of grazing lands more difficult (Lambourne and Little, 1987; Awgichew *et al*., 1989; Saleem and Tedla, 1995) as grazing areas are owned communally.

Animals' feed demand is relatively uniform throughout the year, while grass growth is seasonal. This situation calls for either conservation of surplus growth, or use of supplementary feeds to overcome the deficit (Lambourne and Little, 1987) or limiting the stocking rate by keeping only productive animals. Lack of good quality feed throughout the year is considered as the main bottleneck of the industry and severely influences the reproductive efficiency and health status of animals (Tembely, 1998). Relatively good quality pasture is abundant during the wet season when there is active growth of pastures, the nutritive quality declines drastically as it matures quickly (Gebrehiwot *et al.,* 1987; Lambourne and Little, 1987; Silishi *et al*., 1995). According to Varviko (1993) harvesting and conserving hay as soon as the rainy season ceases and delaying hay making by two months results in a loss of 250 kg ha^{-1} protein, which is nearly the requirement of a crossbred cow in lactation.

Farmers have the tradition of conserving hay and crop residues to be used at a time of feed deficit (Mosi and Butterworth, 1985b; Bediye and Sileshi, 1989b; Yami *et al*., 1991). The importance of crop residues as animal feed is increasing along with the expansion of arable land (Jutzi *et al*., 1987). In Ethiopia, the amount of crop residues, which is a function of area under cultivation and crop types, is estimated to be between 10.7 and 14 million tons DM (Yami *et al*; 1991; Bediye and Fekadu, 2000) and usually lasts for two to three months of collection (ARC and ECA, 1996). Hence, acute shortage of feed is a common phenomenon specifically during the dry season (Sevilla and Carangal, 1995). In areas where the intensification of crop cultivation is high, the deficit extends to the entire cropping season, as animals cannot access to the crop fields (Beyene and Yerega, 1989). The quality of crop residue is influenced by altitude, variety, soil temperature, crop management, and post harvest handling (Getachew *et al*., 1996).

Supplementation of animals with protein sources is imperative to improve the feeding value of crop residues and the output of animals. The straws of food legumes have relatively higher protein contents (Bediye and Silishi, 1989a) and can be used as a protein supplement (Getachew *et al*., 1996). Cakes of noug (*Guozoita abyssinica*), peanut, soybean, and whole cotton seed are also excellent sources of proteins and minerals (Lambourne and Little, 1987).

The current economic scenario of the farmer does not permit purchase of concentrates or protein supplements (Sileshi and Bediye, 1991), Lambourne and Little (1987) recommend the use of expensive supplements if only if it prevents animal death. Other workers including (Jutzi *et al*., 1987; Yami *et al*., 1991; Getachew *et al*., 1996) recommended the use of homegrown forage legumes and multipurpose trees as they can be produced in the farm with reasonably low cost. Mixing cereal residues with legumes is the preferred method of improving efficiency of utilization of residues rather than chemical treatment, which is difficult to apply at the current level of farmers' knowledge (Mosi and Butterworth, 1985a; Mengistu, 1987; Reid and Goe, 1989).

Minerals

Pastures are completely native and grow without the application of either organic or inorganic fertilizers. Mineral content of grazing pasture is influenced by botanical composition of pastures (Long *et al*., 1970; 1972; Kabaja and Little, 1988; Jumba *et al*., 1995 a, b), forage species (Morris, 1987), and season of the year (Shunxiang, 1996; Ramirez-Perez *et al*., 2000; Geleti *et al*., 2001). Availability of adequate minerals in the ration is essential to animal health and higher production. With the exception of common salt Lemma (1995), supplementation of minerals is not practiced at all in the central highlands of Ethiopia. Though it is an established fact that energy and protein are of primary importance to animal productivity, an optimal performance is possible if minerals are supplied adequately (McDowell, 1985). Severe deficiency of minerals in sheep is characterized by loss of appetite, low wool growth, loss of weight and emaciation (Underwood, 1981; Hanjra *et al*., 1996). Nevertheless, milder deficiency may affect sheep productivity even when no clinical symptoms are evident. Works done elsewhere indicate that supplementation of minerals increase productivity (Reis *et al*., 1973; Niven and McMeniman, 1983; Qi *et al*., 1992), and maintains live weight and promote wool growth.

Loss of body weight, low productivity and poor reproductive performance have been reported at times when pasture availability becomes inadequate for maintenance which could be associated with insufficient mineral intakes (Underwood, 1981). It has been implicated by a number of researchers that minerals have an influence on the properties of wool. Effects that could be caused by mineral deficiency as reported by Gillespie (1964) and Purser (1979) include deterioration in crimp and faulty keratisation, small diameter of fleece, poor wool growth and brittle fleece that could readily be removed from the skin when pulled.

Mineral research in Ethiopia is relatively in its infant stage and attention given so far to the mineral status of feeds has been low as compared with other nutrients. In Ethiopia, there are very few reports that show the impact of mineral supplementation on sheep performances (Abera, 1990; Kurtu *et al*., 1991).

Importance of Forage Legumes

Leguminous forage crops are rich in nitrogen, phosphorus and other elements than cereals and grasses and make good supplementary grazing (Lamobourne and Little, 1987). Integration of forage legumes through inter-cropping, under sowing, alley cropping and relay cropping are recommended as options to promote forage legume production as smallholders are reluctant to produce sole forage crops. Several authorities have reported a higher beneficial effect of legumes on soil N and the grain yield of subsequent cereals (e.g. Tedla *et al*., 1995; 1996; Sebsibe and Tsegahun, 1998).

One of the limiting factors for the wide use of herbaceous legumes and browse shrubs is the presence of polyphenolic and tannin compounds, which reduce digestibility even if protein levels are high. This complex phenolic molecules are produced in plants in response to insect attack and browsing animals (Norton, 2000), which affects digestion process in the rumen (Lambourne and Little, 1987; Kumar and D’Mello, 1995). Tannins are secondary plant compounds that are bound with protein by hydrogen bonding at pH 4.0 – 7.0 to form protein complexes, but dissociate and release protein at less than 3.5 pH (Jones and Mangan, 1977). High levels of tannin depress intake (Wiegand *et al*., 1995). Having tannin in a legume may not be regarded as a limiting factor if the tannin levels do not exceed 5 percent of the dry weight (Montossi *et al.,* 1997). Tannins have more positive effects on livestock production through their potential in bloat protection (Jones and Mangan 1977) and antihelimintic properties (Norton, 2000). Tannin content of plants is influenced by species, stage of growth and plant part (leaf, stem, inflorescence, seed), season of growth, temperature, rainfall, cutting and defoliation by grazing herbivores and insects (Norton, 2000).

Tannins in lotus were found to be beneficial by permitting the plant proteins to be digested in the abomasum. Waghorn (1990) using lotus species that contained different levels of condensed tannins (CT) (2.2 and 5.5%), has confirmed that tannins protect dietary proteins from being digested in the rumen. CT in *L. corniculatus* reduces the degradation of forage protein in the rumen, resulting in more wool production with the same level of intake (Min *et al*., 1998). The same authors found that CT reduce sulfur containing amino acids' loss by 30% in the rumen, resulting in an increase of 10% in wool production and quality without affecting voluntary feed intake. Tangendaja and Wina (2000) have reported a growth of 20-60 g day^{-1} in sheep and goats from a feed that contains tannin. The response of sheep to *L. corniculatus* feeding was found to be similar to *Medicago sativa* in voluntary feed intake, body weight, wool growth, and lamb live weight gain (Douglas *et al*., 1995). Drying decreases the apparent content and activity of tannins (Ahn *et al*., 1989).

A brief description of *Lotus corniculatus*

Lotus corniculatus L. (cv. Birds foot trefoils) is a perennial highland forage legume that could resist water logging and frost to some degree. It has shown best adaptation in the degraded highlands of Ethiopia, where the temperature is relatively cool during the growing season. The variety in this genus is given the name “birds foot” trefoils as its ripe seedpods look like a bird's foot. Lotus is a tetraploid perennial forage legume that persists better under low levels of phosphate and potassium and limited availability of plant foods. Due to its tap root system, lotus persist drought, salinity, high water table, poor internal drainage and produces a good amount of biomass. Lotus responds well to chemical fertilizers.

Lotus improves the physical properties of soil by increasing the organic matter content, resulting in lower bulk density, higher infiltration rates and field moisture capacity. It has also a potential to grow in waterlogged and denuded lands, with high tolerance to drought and heavy rotational grazing system (Smethan, 1977). Lotus continues to produce for many years with little or no cost of production if not harvested or grazed close to the ground; and harvested after flowering stage. Smith and Nelson

(1967) noted that cutting height to be more important than cutting frequency in birds' foot trefoil and with no report of bloat (Smethan, 1977). This has been found to be due to the low water solubility of the leaf protein coupled with the presence of tannins (Jones and Lyttelton, 1971). Lotus is getting high acceptance in the central highlands of Ethiopia especially in areas where water logging is a major problem and fallowing is a common practice as it can be planted at leisure time, if there is sufficient shower for establishment. Lotus can be planted both by seeds and root splits. Early works at Sheno Agricultural Research Center (SARC) revealed that vegetative plantings give a higher biomass yield than that of the seeds. Lotus could be an option to concentrate feeding for animals that rely on poor quality dry pasture for most parts of the year (Sebsibe and Tsegahun, 1998).

Two species of lotus have been introduced in the central highlands by SARC. Among them, *L. corniculatus* was found to be hardy, tolerant to drought and gave a higher biomass than *L. pedunculatus*. The agronomic, chemical, and mineral constituents of the two lotuses are given in Table 3 and 4. *L. corniculatus* is further spreading, as it can be planted even in the wet season, while the land is submerged under water. The neutral detergent fiber (NDF) and acid detergent fiber (ADF) values of both varieties were found to be similar, though the CP (crude protein) value of *L. pedunculatus* seems a little bit higher than *L. corniculatus*.

Table 3 Chemical and mineral composition of *L. corniculatus* and *L. penduculatus*.

	DM%	Ash	NDF	ADF	CP	Lignin	ADF ash	Na ppm	K %	Ca %	Mg %	P %
L. corniculatus	90.06	9. 39	38.78	27.61	13.94	4.67	3.41	28.63	1.86	2.73	0.44	0.12
L. penduculatus	90.55	11.07	37.79	27.49	14.69	3.89	3.44	385.34	1.96	3.06	0.44	0.14
Mean	90.31	10.23	38.29	27.55	14.32	4.28	3.43	206.99	1.91	2.90	0.44	0.13

Table 4 Some agronomic performances of *L. coniculatus* and *L. penduculatus***.**

	L. corniculatus	*L. penduculatus*
Plant height (cm)	56.2	13.94
Planting time	June/July	June/July
Harvesting time	Late December	Early December/ late November
Seeding -harvesting	150±9days	120±4 days
Seeding rate (kg)	10	10

A brief description about sheep breeds used in the experiment Menz Sheep

The Menz sheep with an estimated population of 1.5 million, are indigenous to the study areas that stretch between 39° to 40° E longitude and 10° to 11° N latitudes ranging from 2,500 to 3,400 m asl where fleece harvesting and utilization play a great role in generating income (Devendra and McLeroy, 1982; Gatenby, 1986). The Menz sheep (Figure 1) are of small body size and have short necks, straight backs, and small heads. While the rams are identified by their long and twisted horns, the females have short vestigial horns (Mukasa-Mugerwa and Lahlou-Kassi, 1995). The usual color of the Menz sheep is black or dark brown with white patches on the head, neck and legs (Devendra and McLeroy, 1982; Gatenby, 1986; Mukasa-Mugerwa and Lahlou-Kassi, 1995). They have fat tail that stop half way to the hocks with a slight short twist at the end. Based on tail type (Devendra and McLeroy, 1982; Gatenby, 1986; Mukasa-Mugerwa and Lahlou-Kassi, 1995) classified the sheep as a fat tailed sheep.

The Menz sheep are reared for their meat and wool values (Awgichew, 1987; Mukasa-Mugerwa and Lahlou-Kassi, 1995). The lambs on average weigh 1.9 – 2.7 kg and 12.3 to 16.1 kg at birth and at weaning, respectively (Awgichew *et al*., 1991; FAO, 1991), while the average mature body weight ranges from 25 to 35 kg for ewes and 35 to 45 kg for rams (EARO, 2000). The Menz sheep attain puberty at the age of 350±12 days with an average weight of 16.9±0.1 kg and are bred at 8.4 months interval lambing three times in two years with a gestation period of 149 days (Mukasa-Mugerwa and Lahlou-Kassi, 1995). Ewes cycle year round Awgichew *et al*. (1991) and are bred throughout the year with little seasonal influence (Mukasa Mugerewa *et al*., 1994). With a frequency of less than 10% twinning is not common (Awgichew *et al*., 1991) due to embryonic mortality (Mukasa- Mugerwa and Tekeleye, 1988).

The Menz sheep are shorn at least once in a year manually using hand shearer. Preliminary investigations indicated an average fleece yield of 0.5 kg per head per annum (Ageyemang *et al*., 1985; Mukasa-Mugerwa and Lahlou-Kassi, 1995; Lemma *et al*., 1998). With twice shearing, Devendra and McLeroy (1982) reported a yield of 1.0-1.6 kg. The major portion of the coarser fleece is used in cottage industries to weave carpets, blankets, hat, cloaks, etc. (Galal, 1982), while some amount goes to whole sellers to be used in the production of mattresses and pillow stuffing. Devendra and McLeroy (1982), Galal (1983) estimated the staple length of wool to be 5-8 cm, while that of hair to reach 10-20 cm.

Figure 1 Menz sheep.

Tukur Sheep

The Tukur sheep with an estimated population of about 0.5 million, is found mostly in the districts of Lasta, between the administrative regions of Wello and Tigray at an altitude of 2800-3400 m asl (Lemma *et al*., 1998). The Tukur sheep, which is extremely hardy, is classified as fat tailed sheep (Devendra and McLeroy, 1982; Gatenby, 1986) having moderately large body size with well-developed horns in the rams (Figure 2). The sheep was reported by Devendra and McLeroy (1982) to produce 2 kg fleece, while Awgichew (1987) estimated as low as 0.5 kg per head per annum. The fleece contains fine and coarse fibers with a staple length of 10 cm and is used for cloaks and blanket weaving.

Figure 2 Tukur sheep.

Awassi Sheep

The Awassi sheep is a multi purpose (wool, meat and milk) fat tailed sheep that originated in western Asia. The males are horned (Figure 3) while the females are polled and the breed color is white with a dark red or brown head. Awassi sheep with its coarse wool is classified as a carpet wool breed. Devendra and McLeroy (1982) have reported a fleece weight of 2.0 kg for ewes and 3.9 kg for rams with a fiber diameter of 30-35 μm and staple length of 10-15 cm.

Figure 3 Awassi×Menz sheep.

Sheep Management

Sheep are reared traditionally leaving every thing to nature and more emphasis is put on the increase in number rather than the level of productivity per head. The production system in the mixed agricultural system of Ethiopia is a low-input-low out put system with no specialization. However, the system seems more efficient in the utilization of available resources making both productivity per head and production costs low (Vercoe *et al*., 1997). Doney (1983) concluded that it is the best-suited system and stressed on the efficiency of the system which requires low labor and capital investment. Though it serves as an important cash-generating component, (Awigchew *et al*., 1989; Alemayehu and Fletcher, 1993) the financial return from sheep is not impressive enough to motivate farmers for additional inputs to improve productivity

(Awgichew *et al*., 1991; Mekonen *et al*., 1991). As a result, production increase from the traditional system either has been levelled off or has declined, calling for an intervention to raise production per head. The two priority options suggested to boost production are health intervention and better feeding and management (Niguisse, 1987). With the aim of acquiring higher body weight and better price, it is common to observe castrated sheep in any typical village. Castrated sheep get preferential treatments for longer period (Awgichew *et al.,* 1991; Alemayehu *et al*., 2000a). However, findings by Tiyo *et al*. (1988) did not support the high rate of growth of castrated rams.

Sheep Diseases

Disease is the main cause for loss of young lambs (Awgichew *et al*., 1991). At the national level, the estimation of mortality goes up to 10-20% Awgichew (1987), while Alemayehu and Fletcher (1993) estimated 23% for the central highlands. Diseases cause high economic losses as they lower performance (milk, meat, and fiber); entail poor reproductive efficency, condemnation of affected organs and carcass, and in severe cases, death of the animal. Vulnerability of young stocks to diseases has been ascertained by numerous research results. According to (BoA, 1999a; Benin *et al*., 2002), the major diseases of the area include anthrax, blackleg, contagious bovine pleuro-pneumonia, pasteurellosis, rinderpest, trypanosomiasis, sheep and goat pox, and African horse sickness. Shortage of feed that usually occurs during the dry season renders animals more susceptible to parasitic infections. Grazing areas are not rested long enough to interfere with the life cycle of worms and parasites; and become a potential reservoir of various diseases and parasites that could inflict great damage to the industry (Mulugeta *et al*., 1991).

Wool growth

The serrated surface, a crimp wavy appearance; an excellent degree of elasticity and an internal structure composed of numerous minute cells make wool different from other animal fibers (Ensminger and Parker, 1986). Wool is 100% protein composed of amino acids. Its chemical composition contains 50% carbon, 22-25% oxygen, 16-17%

nitrogen, 7% hydrogen, and 3-4% sulfur (Ensminger and Parker, 1986; Botkin *et al*., 1988). Wool provides insulation, giving the sheep the ability to withstand severe cold or hot climate. The fleece gives mechanical as well as insulative protection. A 5 cm-long fleece provides heat insulation equivalent to a temperature gradient of 40^0C (Ryder, 1987; 1993). The fleece therefore, saves food that would otherwise be consumed to keep the sheep warm.

Wool formation and production is a non-stop process Russel (1992) and requires a continuous supply of nutrients apart from maintenance. Wool growth continues even under sub maintenance intakes while body weight is being lost (Owen, 1976; Ferguson, 1979; Squires, 1979). Competition for nutrients particularly during growth and lactation is very high. Environmental factors such as photoperiod, temperature, nutrition, physiological state and genotype Russel (1992) play an important role in controlling fiber growth.

The major nutrients that determines wool production are proteins specifically those sulfur-containing amino acids of methionine and cystine. Energy intake has also an influence on wool production particularly at high levels of protein intake. Protein is constantly demanded for uniform wool growth because wool comprises keratin. Sheep can synthesis cystine in the rumen from the amino acids of methionine and cystine absorbed in the small intestine. Increasing the supply of cystine and methionine to the sites of absorption in the small intestine improves the production of wool as methionine plays a great role in the synthesis of keratin. Variations in the availability of the sulfur amino acid cystine to the follicle affect fiber growth rate and composition. Wool, kemp and hair are the three types of fiber found in the coats of sheep. Wool fibers are the finest, while kemp fibers are the coarsest of all and hair fibers are an intermediate one between the wool and the kemp fibers.

Coombe (1985) reported significant weight change on wool but with no significant differences between diets due to protein diet supplementation. Several workers including (Messenger *et al*., 1971; Entwistle and Knights, 1974; Barry and Drew, 1978; Wheeler *et al*., 1979; Hawker and Thompson, 1987) did not find treatment effects on greasy wool production, fiber diameter and staple length. McGregor (1988) and Sahlu *et al.* (1999) did not obtain any effect of nutrition on cashmere growth and mohair diameter. Min *et al.* (1998) reported no treatment effect on fiber diameter, length, bulk density and wool resilience; though a reaction in wool production was reported. On the other hand a number of authorities have reported the effect of supplementary feeding on wool production (e.g. Owen, 1976; Ryder, 1987; Lemma *et al.*, 1991; Obst *et al.*, 1991). Wool growth rate follows the pattern of live weight gain. Usually, lambs with heavier body weight produce correspondingly higher wool with the exception of Merino breeds (Ryder, 1993). Fleece yield is more influenced by breed rather than treatments (Gatenby *et al.*, 1997). Poor nutrition reduces fiber diameter (Hunter *et al.*, 1990) and enhances fleece shedding (Owen, 1976).

Wool production and quality is determined by fleece characteristics including greasy yield, staple length and fiber diameters which make the most important fleece characteristics that are highly valued as the yardsticks for quality by both producers as well as the manufacturer (Ensminger and Parker, 1986). According to Onions (1962), cited by Gatenby (1999) wool needs to have at least 40-50 µm diameter to be classified as carpet wool; 30-45 µm to be classified as luster long wool; 25-30 µm as cross breed and 18-24 µm as Merino.

Wool Production and Marketing

Wool is the most important product of sheep and has a high demand for the manufacturing of clothing and carpets. Wool holds the primary and perhaps the only position of economic product in the extreme highlands of Ethiopia, where crop production is less intensive. Coarse fiber has a direct use for the farming families and artisans. Payne and Wilson (1999) estimated a production of 12,500 tons of greasy wool per annum that could be used by weavers willing to pay high price for color and quality. The blanket factory located close to the wool bearing sheep of the central highlands of Ethiopia currently uses insignificant amount of locally produced wool; while expending nearly 13.36 million birr/annum (1USD=8.60 birr in 2003) to import about 1.60 million kg of raw materials. This is mainly because of the poor quality of the local produce that does not meet the factory's requirements.

The local markets lack the necessary infrastructure for wool marketing. Wool is traded off through bargaining. No standard is available to categorize the fiber based on its quality, color, or length. Thus, pricing depends on bargains that do not motivate producers. Spun wool threads fetch better price than the loose ones. No attempt has been made so far to set up an organized wool market. Documentation of demand and supply of fleece, amount supplied and sold on each market day and the number of cottage industries and their capacity that are involved have not been carried out by the responsible authorities. However, it seems that the demand for coarse fleece is met by the local production. The high demand for fiber by artisans and the blanket factory indicates the availability of a big market that is ready to be exploited. However, a strong extension program has to be launched to improve the quality of the produce and enable the farmers make a living out of it.

Supplementation and Effect of Season on Wool Production

Supplementation of low quality roughage with herbage of high CP content is more likely to increase wool production in proportion to the increase in intake of total digestible nutrients than in proportion to the increase in nitrogen intake. In terms of wool production, the total digestible organic matter consumed is more important than the overall level of dietary nitrogen (Robards *et al.*, 1976). The positive correlation between adult size and fleece weight certainly suggests that any residual effects of early growth retardation result in a reduction of potential wool growth throughout the adult life (Doney, 1983). Poor nutrition affects wool quality (Ensminger and Parker, 1986; Botkin *et al.*, 1988; Rusel, 1992) and fiber diameter (Ryder, 1993). The effects of poor nutritional regimes either imposed for short periods or continuously, have profound consequences as regards to the tensile properties and processing performance of wool. Hunter *et al.* (1990) reported a difference of up to 10 μm between the mean diameters of fiber segments grown during periods of nutritional stress and normal feeding.

Rowe *et al.* (1989) working with Merino sheep found that supplements of 750 g grain increased clean fleece weight from 2.65 to 3.59 kg, wool fiber diameter from 18.6 to 21.1 μm, and staple length from 73.5 to 86.7 mm. In New Zealand, feeding *L. corniculatus* increased the amount of clean fleece weight from 2.28 to 2.53 kg/ewe and staple length 6.9 to 7.74 cm (Min *et al.*, 1998). In their supplementation studies to determine the response of wool growth to rumen protected methionine, Rodehutscord *et al.* (1999) achieved twice yield increment of clean wool growth from heat-treated lupin and formaldehyde than untreated lupins (19%).

McManus and Reynolds (1976) using different levels of wheat (3.9 to 7.1 kg head^{-1}) have found a linear response for clean wool weight and staple length with an increase in wheat values and a curvilinear for fiber diameter. In a feeding trial of air-dried Lucerne pellets at 594, 750, 951, and 1097 g per day using wool sheep selected for their skin quality, Robards *et al.* (1976) found that wool production increased with an increase in intake. However, the efficiency of wool production declined with increasing intake in all groups of sheep. In another trial using Merino sheep selected for crimp and fed with 623, 767, 911, and 1054 g of pelleted Lucerne, Robards *et al.* (1974) found that wool production per day and per unit area increased, whereas efficiency of wool decreased as the daily intake increased.

Drenching methionine in the form of MeMHA (Metyl ester of MHA) and EMHCL (Ethyl ester of methionine hydrochloride) was reported by Wheeler *et al.* (1979) to increase wool production by 30% on native pasture and 4% on improved pasture. Addition of dietary ruminally-undegraded protein increased mohair production with and without somatotropin treatment in yearling Angora goats (Davis *et al.*, 1999). Using Angora kids, McGregor (1986) showed that improved nutrition increased mean fiber diameter by 0.2 μm per kg live weight increase. In a work done on cashmere, McGregor (1988) found that goats fed under maintenance energy produced less and finer cashmere (146 g, 16.7 μm) as compared with those received higher than maintenance levels (221 g, 17.7 μm).

Seasonal rainfall pattern markedly influences seasonal pasture growth resulting in seasonal wool growth (Williams and Suijdendorp, 1968) which varies considerably throughout the year. Supplementation reduces the rate of live weight decline, and wool production follows the pattern of live weight (Brown, 1976; FitzGerald, 1976). Although the relationship between nutritional status and wool production has been well-established, little information is available on the effects of season on wool production. Experiments conducted to evaluate the effect of season on wool growth have shown that wool production and its quality are better in summer than in winter (e.g. Bigham *et al*., 1978; Hal, 1987; Summer and McCall, 1989). Live weight loss can be regained through compensatory growth during subsequent period of good nutrition. However, there is no evidence for compensatory wool growth (Coombe *et al*., 1987). The quantitative and qualitative changes in nutrition available to sheep in the course of the year tend to be associated with season. However, the amplitude and timing of the cycles of growth deferred among breeds (Doney, 1966).

Entwistle (1975) using high and low quality feeds and a simulator of high and low temperature found that environmental temperature had little effect on wool growth rates when nutrient intake was not limiting. However, in a field condition, effect of temperature could have an indirect effect by reducing grazing time of the poor quality pasture resulting in low feed intake, which leads to a reduction in wool production. The effect of nutrition in one season can affect wool production of the coming seasons. Working in Merino sheep, Rowe *et al*. (1989) observed a carry over effects of supplementary feeding during summer and autumn on wool growth during winter.

Blood

The blood serves as a transport media and provides information on the nature of disease, extent of injury to tissues and organs of the body responsible for defense mechanism. Nutritional deficiencies, metabolic disorders, and diseases can be detected by analysis and monitoring of blood and other body fluids (Rowlands *et al*., 1975). Various factors influence the normal blood values of animals. Schalm *et al*. (1975), Coles (1986), Taffese (1987), Jain (1993), Abunna (1999) and Tibbo *et al*. (2005) stated that age, sex, breed, nutrition, health and physiological status (such as pregnancy, parturition, oestrus, animal excitement, muscular activity, time of sampling, ambient temperature, water deprivation and altitude) could influence the normal blood values of an animal.

Hemoglobin (Hb) is highly age and sex dependent and is expressed as a unit mass per volume, specifically grams per deciliter (g/dl) is more related with O_2 carrying capacity. A drop in Hb count indicates hemolytic disease of Babesioses, Anaplasmosis and Leptospirosis (Schalm *et al.,* 1975). Total protein (TP) which is expressed as grams per deciliter (g/dl) is a constituent of albumin, globulin and fibrinogen; that can be altered by edema, ascites, infections, coagulapathies, diarrhea, weight loss, renal and hepatic disease and treatment (Davis *et al*., 1999).

Packed cell volume (PCV) which is a measure of total volume of the erythrocytes relative to the total volume of whole blood in a sample, is usually expressed in percentages (Schalm *et al*., 1975; Coles, 1986; Jain, 1993). The percentage of blood volume occupied by PCV is used in clinical medicine as an index of anemia, assessing of blood parasites and overzealous fluid therapy. The more anemic, the lower the PCV count. Animals with PCV< 24 percentage are considered anemic (Kelly, 1974).

The normal range of Hb and PCV varies among 9 to 15 (g/dl) and 24 to 40% respectively (Schalam *et al*., 1975; Jain, 1993; University of California, 2004), which holds true also for the central highland sheep of Ethiopia (Abunna, 1999; Tibbo *et al*. 2005). The effects of physiological state on red blood cells (RBC) were reported by Abunna (1999). Accordingly, sheep in oestrus have higher RBC than those out of oestrus, and pregnant ewes have lower RBC, PCV, and Hb concentration. No difference was reported between sexes in any of the hematological parameters (Tibbo *et al*., 2005). Several investigators demonstrated that age affects the hematological parameters of sheep. Abunna (1999) has found that a lower percentage of PCV and an increase of RBC count as the age of the sheep increased, while Tibbo *et al*. (2005) did not find an effect of age on erythrocytic series apart from a decreasing trend of lymphocytes and a rise of neutrophils as age increased.

Red blood cells, PCV and Hb values are found to be influenced by the nutritional status of the animal (Thahar *et al*., 1983; Oyedipe *et al*., 1984; Taffese, 1987). Sheep fed with good quality feed had higher RBC, PCV and Hb. An increase in RBC count was observed as the exotic blood level increased in Awassi crosses (Abunna, 1999). The Menz sheep showed a lower RBC count when compared with the Awassi sheep (Abunna, 1999; Tibbo *et al*., 2005). Among the highland sheep of Ethiopia Tibbo *et al*. (2005) reported a higher count of RBC and PCV and low level of Hb in Menz sheep than in Wello and Tukur sheep. Effect of breed on RBC count has been reported (Schalm *et al*., 1975; Coles, 1986; Jain, 1993; Abunna, 1999; Tibbo, *et al*., 2005) in various animal species. An oxygen tension in the higher altitudes leads to an increased production and release of erythropoietin that stimulates erythropoiesis (an increase in circulating erythrocyte number, hemoglobin concentration, and PCV percentage) as a coping or adaptive mechanism to low oxygen level. A number of investigators have substantiated this fact (e.g. Schalm *et al*., 1975; Coles, 1986; Jain, 1993).

Considering the prevailing climatic situation of the central highlands of Ethiopia, Tibbo *et al*. (2005) have found that all erythrocyte series to be affected by season, with the exception of Hb and mean corpuscular volume (MCV). RBC and PCV were highest during the dry and short rainy seasons than in rainy and the period immediately following the rainy seasons. This might be partly associated with sub-clinical parasitism. RBC and PCV were highest during the dry and short rainy seasons than the rainy and the period following the rainy season. In contrast with Hb, mean corpuscular hemoglobin concentration (MCHC) and white blood cells (WBC) were highest during the rainy and the period following the rainy seasons than during the dry and short rainy seasons.

MATERIALS AND METHODS

Experiment I. Feed Survey and Sheep Production Systems in the Central and North-western Parts of Ethiopia.

A survey which focused on feeds and small ruminant husbandry was conducted in the Amhara Regional State of Ethiopia. The political boundary of the Region is defined as the area between longitudes of 35° 46' to 40° 25' E and latitudes of 8° 45' to 13° 45' N. The survey area is depicted in relation to Ethiopia as a whole in Figure 4. By the virtue of being mountainous, the region consists of all the three major agro ecological zones: namely high, medium, and lowlands. The diversified climate enables the region to grow different types of crops such as tef, wheat, sorghum, maize and a variety of pulse and oil crops. The surveyed districts experience a bimodal type of rainfall June to September being the main rainy season and March-May covering the small rainy season (Annex 1). Precipitation peaks are late in July to early August and in April, respectively. The long-term average annual rainfall of the area is about 970 mm, with mean maximum temperature of 24.3°C in June and mean minimum temperature of 4.96°C in October. A frost hazard exists at elevations above 1400 m from October to January and causes considerable crop damage above 1800 m. Characteristics of the soil vary from place to place.

Sampling techniques and site selection

The survey mainly focused on feed-resource-base and small ruminants' production system was conducted in the districts of Debark, Wegera, Farta, Lai Gayint, Meket, Wadela, Were Ilu, Tenta, Gera Keya and Lalo Midir, using purposive sampling techniques. In the selection of the districts and actual sites, accessibility, number of sheep population and experience in fleece production were taken as criteria. In identifying the districts and specific sites, initial consultation was made with the concerned officials of the region and each district. In each districts three sites were selected based on their agroecologies (high, medium and lowlands), and at least 10 percent of the community were interviewed for the preset questionnaire in each site

(Annex 4). The concerned Ministry of Agriculture (MoA) staffs have shown active participation in the collection of samples and conducting of interviews. Since accessibility was difficult in the low-lying areas, lowlands of some districts have been excluded from the survey.

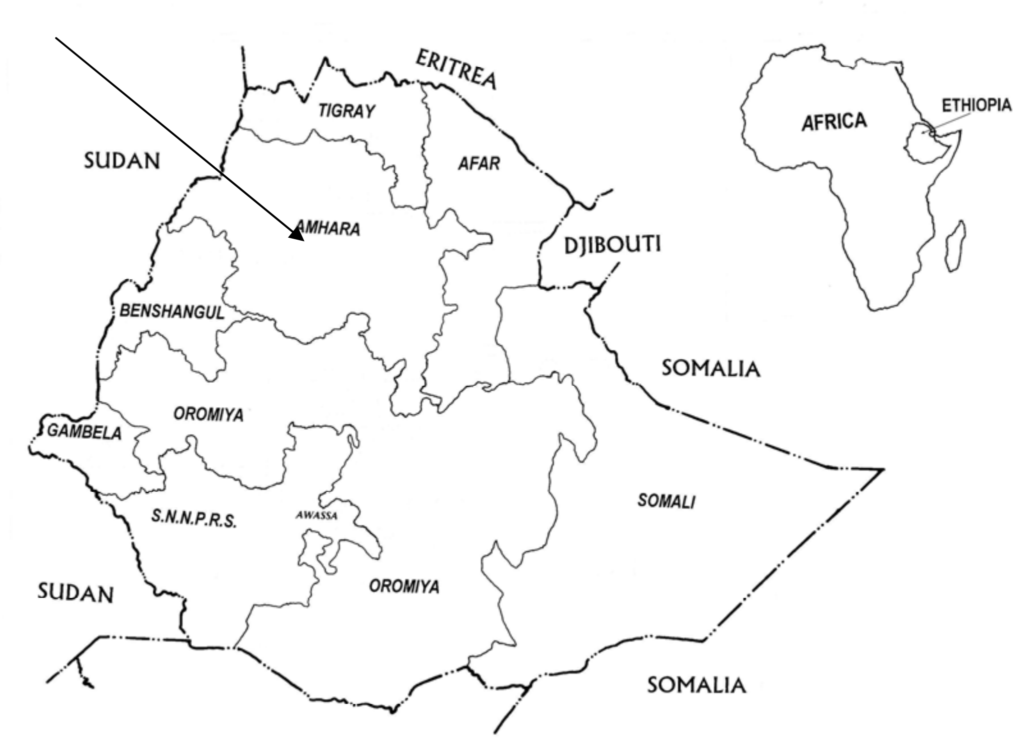

Figure 4 Map of Ethiopia and location of the Amhara Administrative Region.

Data collection and analysis

Using structured questionnaire, information on source of income, purpose of production, reason of animal sale, supplementation strategy, cost of supplements and general constraints to sheep production was obtained from the discussion made with the farmers. The data was coded and comparisons were made purely on percentage or absolute number basis.

Grain yield data were used to estimate their equivalent residue yields using the conversion factors of (Kossila, 1988; Nordbloam, 1988 and Yami *et al*., 1991). Animal numbers were converted to the standard unit of Tropical Livestock Unit (TLU). The TLU is expressed as a bovine that is equivalent to 250 kg on maintenance level, as 1 cattle, 1 sheep, 1 goat, 1 horse, 1 ass and 1 mule equals 0.6, 0.08, 0.07, 0.9, 0.6, and 0.9 TLU, respectively (Kossila, 1988), and 1 camel 1.0 TLU.

Experiment II Chemical and Macro Mineral Comparison of Feedstuffs Collected from the Central and Northern-Western Parts of Ethiopia.

Sample Collection

Representative feed samples were collected from each site after making a close observation of grazing animals and consulting with farmers. In each site, discussion was made with a group of farmers to obtain a more reliable and firsthand information. Sampling was made from mid-October to early-November 2002 when the fodder and browse species were green and the dry-season sampling was made in May.

Types of feed collected

Samples of all potential feed resources that are being used as animal's feeds specifically browses, cultivated and uncultivated forage crops, crop residues, hay, home and industrial byproducts (oil meals, grain-bran and local brewery) were collected for the study. Identification of the fodder shrubs, grasses, and legumes was made on the spot, and further confirmed in the herbarium of the Biology Department of the Addis Ababa University. All samples were coded and information concerning the location, altitude, season, stage and local name of the plant was gathered on the spot.

Sample preparation

The samples were labeled and transported to SARC. In the Center, each sample was dried in a forced-draught oven at 65^{o}C for 72 hours to a constant weight, ground to pass through 1 and 2 mm sieves and stored in an airtight container at room temperature until analysis was performed.

Feed analysis

Analyses were done for dry matter (DM), ash and nitrogen according to AOAC, (1990). NDF and ADF were determined according to the methods outlined by Gorieng and Van Soest (1970). Hemicellulose was determined by taking the difference between

NDF and ADF. Ca, Mg, Na, and K were determined using atomic adsorption spectrophotometer and P was determined using Auto Analyzer following the procedures outlined by Chemical Laboratory Instrument Methods No. W2-075-01. The *in situ* degradability was done by incubating the feeds in the rumen of six steers for 0, 3, 6, 9, 12, 24, 36, 48, and 72 h (Ørskov *et al*., 1980).

The macro mineral concentration of the feeds were categorized into deficient, borderline and sufficient based on the mineral requirement of sheep as outlined by McDowell (1997). Minerals below the set standard were categorized as deficient, and those within the range were classified as borderline and those above the requirement were rated as sufficient level.

Statistical analysis

The analyses of variance were computed using the Statistical Analysis System (SAS, 1999) procedures.

Experiment III The Effect of Supplementation of *Lotus corniculatus* Hay on Body and Fleece Weight of Sheep Grazing Natural Pasture in the Dry Season.

Experimental Site

The trial was carried out at Debre Berhan Research Center (DBRC). The center is located 120 km northeast of Addis Ababa at an altitude of 2780 m asl adjacent to the main road to Dessie. It is situated within the coordinates of 9^{o} 36' N latitudes and 39^{o} 38' E longitude. Meteorological data indicate that the area receives an annual rainfall of 900 mm with a minimum and maximum temperature of 0.90 and 21.95^{o}C, respectively. The area experiences frost and chilling when the night temperatures fall below freezing point during October-January. Detailed metrological data are given in Annex 2.

Feed production and preparation

Lotus *(L. corniculatus)* was grown at SARC and harvested manually with hand sickles. The sun-cured lotus was then stacked in sacks and kept in roofed but open-sided hay-shed till used for the experiment.

Animal management

Menz and Tukur yearling male lambs previously raised on pasture were purchased from their original places and shipped to the research center. First crosses of A×M were obtained from SARC. Ages of the sheep were determined by dentition for the Menz and Tukur sheep and were below 12 months old at the time of purchase. Record sheet was used in selecting the crosses.

The sheep were tagged, weighed, sprayed and drenched for internal and external parasites using broad-spectrum antihelmentic (albendazole) and Fasinex on arrival and were left to acclimatize to the new environment. Initial weights obtained by weighing for two consecutive days were used to allot sheep to groups so that the mean and standard deviation of group-weights were similar across treatments of the same breeds. Sixty lambs, twenty from each breed of Menz, Tukur, and A×M with initial weights of 20.25, 21.09, and 19.78 kg, respectively, were used as experimental animals. The sheep were allocated to the four levels of diets by stratified randomization based on live weight and breed. The lambs were acclimatized to the feeding treatments for two weeks before the commencement of the experiment and were supplemented with sun-cured lotus hay at 0, 100, 200, and 400 g day^{-1} head^{-1} in their respective individual pens. No residue was observed throughout the experimental period.

The feeding period lasted for 120 days starting from March 2003. The animals were managed together as a single flock during the daytime grazing on unimproved natural pasture dominated by *Trifolium, Festuca, Andropogon,* and *Pennistum*. Water was supplied *adlib* three times a day and was free of choice during the enclosure time; with no mineral supplementation. Body weight was measured fortnightly prior to watering and feeding. Blood samples were collected once a month, before weighing which coincide with the weighing date.

During the experimental period, the flock was separated at all times from other sheep units to minimize the risk of disease transmission. Grazing pegs were used to demarcate the grazing area, used specifically for the experimental lambs. The grazing area was sub-divided into four equal paddocks whereby the flock stays for a week only in each paddock exercising rotational grazing.

Pasture sampling

The grazing fields was sampled every week by clipping the sample at ground level using a quadrant of 0.5x0.5 m (0.25 m^2) from randomly selected points of each paddock before grazing. The sample was dried in an air-forced draught oven at 65^{o}C for 72 hours until it reached a constant weight. Dried forage was composed within paddocks on a monthly basis, ground to pass through a 1 mm sieve, and was kept at room temperature until analyzed for DM, ash and nitrogen (AOAC, 1990), ADF and NDF (Goreing and Van Soest, 1970).

Carcass analysis

Body weight gain was calculated as the difference between body weight taken at the start and end of the experiment. At the end of the experiment, lambs were held of feed and water overnight and slaughtered the next morning after weighing.

Wool samples

Fleece yield was determined by shearing the sheep at the end of the experiment. Mid side patches of each side of the sheep were clipped from an area of approximately 10x10 cm just prior shearing. The clean weight was determined after scouring in a degreasing solvent. Excess moisture was removed by drying in an oven until a constant weight was obtained for 24h. Wool staple length was determined by measuring the length of randomly chosen staples, while mean fiber diameter was measured using a projection microscope.

Blood analysis

Blood samples were obtained by jugular puncture on a monthly basis throughout the experimental period before weighing and the sheep went for grazing. Potassium oxalate was used to prevent coagulation of the collected blood. Packed cell volume (PCV) was determined by the microhematocrit method, centrifuging at 1200 rpm for 10 minutes. Acid haematin method was used to determine hemoglobin (Hb) concentration using Sahli- Hellings hemoglobinometer (Fisher Scientific Loughrough, UK).

Experimental Design

A 4x3 factorial arrangement four levels of feeding (0, 100, 200 and 400 g $h^{-1}d^{-1}$) and three breeds (A×M, Menz and Tukur sheep) was used to lay down the experiment. Differences between diets, breeds and their interactions of all parameters were considered. Analysis of variance was done using GLM procedures of SAS (1999) statistical packages to test differences. Least square means and their corresponding standard error are presented for each parameter.

$$Y_{ijk} = \mu+b_i+t_j+bt_{ij}+e_{ijk}$$

Where Y_{ijk} = Means for responsible variables
μ = Overall mean
b_i = Breed effect
t_j = Treatment effect
bt_{ij} = Interaction
e_{ijk} = Error term

Experiment IV. The Effect of Mineral Supplementation on Live Weight Gain and Fiber Production of Three Sheep Breeds in the Central Highlands of Ethiopia.

Two flocks were formed from three breeds and were assigned into mineral supplemented and un-supplemented groups using the mean body weight of each sheep that was taken for two consecutive days. All sheep were managed in a single flock and allowed to graze during daytime from 8:00 to 17:00 h on unimproved natural pasture dominated by *Trifolium, Pennistum, Andropogon,* and *Festuca*. The grazing-field was sampled every week and bulked on a monthly basis for laboratory analysis. The experiment was conducted during the main growing season (July-October, 2003), where there was enough green pasture for grazing. A mineral block with an average weight of about 1068 g was given for each lamb at the beginning of the experiment. The mineral-mix was formulated to contain 18.80% Ca; 2.80% P; 31.20% NaCl; 0.09% Mg; 0.084% Mn; 0.17% Zn; 0.0068% I; 0.055% Cu; 0.115% Fe; 0.0009% Co and 0.0004% Se. The weight difference of the block was used to determine the amount of mineral licked in each week. Body weight was measured fortnightly prior to watering and feeding over night. Blood samples were collected once in a month by adjusting with the weighing dates. All sheep were sheared and slaughtered at the end of the experiment to measure the fiber and carcass traits.

Animal management.

Menz and Tukur yearling male lambs previously raised on pasture were purchased from their original places and shipped to the research center. First crosses of A×M were obtained from SARC. Ages of the sheep were determined by dentition for the Menz and Tukur sheep and were below 12 months old at the time of purchase. Record sheet was used in selecting the crosses.

The sheep were tagged, weighed, sprayed and drenched for internal and external parasites using broad-spectrum antihelmentic (albendazole) and Fasinex on arrival and were left to acclimatize to the new environment. Initial weights obtained by weighing for two consecutive days were used to allot sheep to groups so that the mean and standard deviation of group-weights were similar across treatments of the same breeds. Twenty-four lambs were grouped in to two groups (un-supplemented and supplemented) with initial weight of 20.88±0.91 and 20.35±0.91 kg, respectively. The sheep were allocated to the two levels of diets randomly based on live weight and breed. The lambs were acclimatized to the feeding treatments for two weeks before the commencement of the experiment which lasted for 120 days.

The animals were managed together as a single flock during the daytime grazing on unimproved natural pasture dominated by *Trifolium, Festuca, Andropogon,* and *Pennistum*. Water was supplied *adlib* three times a day and was free of choice during the enclosure time; with no mineral supplementation. Body weight was measured fortnightly prior to watering and feeding. Blood samples were collected once a month, before weighing which coincide with the weighing date.

Pasture sampling.

Herbage mass of the grazing area was estimated every week by clipping the sample at ground level using a quadrant of 0.5x0.5 m (0.25 m^2) from randomly selected points of each paddock before grazing. The sample was dried in an air-forced draught oven at 65°C for 72 hours until it reached a constant weight. Dried forage was composed within paddocks on a monthly basis, ground to pass through a 1 mm sieve, and was kept at room temperature until analyzed for DM, ash and nitrogen (AOAC, 1990), ADF and NDF (Goreing and Van Soest, 1970) methods.

Carcass analysis.

Body weight gain was calculated as the difference between body weight taken at the start and end of the experiment. Prior to slaughtering the animals were deprived of water and feed for 12-14 hours. Hot carcass weights and weights of different parts were measured after the slaughter.

Wool samples.

Fleece yield was determined by shearing the sheep at the end of the experiment. Mid side patches of each side of the sheep were clipped from an area of approximately 10x10 cm just prior shearing. The clean weight was determined after scouring in a degreasing solvent. Excess moisture was removed by drying in an oven until a constant weight was obtained for 24h. Wool staple length was determined by measuring the length of randomly chosen staples, while mean fiber diameter was measured using a projection microscope.

Blood analysis.

Blood samples were obtained by jugular puncture on a monthly basis throughout the experimental period before weighing and the sheep went for grazing. Potassium oxalate was used to prevent coagulation of the collected blood. PCV was determined by the microhematocrit method, centrifuging at 1200 rpm for 10 minutes. Acid haematin method was used to determine hemoglobin (Hb) concentration using Sahli- Hellings hemoglobinometer (Fisher Scientific Loughrough, UK).

Experimental Design

A 2x3 factorial arrangements two levels of mineral supplementation (supplemented and un-supplemented); and three breeds (A×M, Menz and Tukr sheep) was used to lay down the experiment. Differences between diets and breeds and their interaction of all parameters were considered. Analysis of variance was done using GLM procedures of SAS (1999) statistical packages to test differences among means. Least square means and their corresponding standard error are presented for each parameter.

$Y_{ijk} = \mu + b_i + t_j + bt_{ij} + e_{ijk}$

Where Y_{ijk} = Means for responsible variables
μ = Overall mean
b_i = Breed effect
t_j = Treatment effect
bt_{ij} = Interaction
e_{ijk} = Error term

Experiment V. Effect of Natural Pasture Hay and Barley Straw Supplementation on Live Weight Gain and Fleece Production of Three Sheep Breeds in the Central Highlands of Ethiopia.

Three groups were formed from each breed based on body weight and was randomly assigned to one of the treatment groups (grazing only, grazing + hay and grazing + barley straws group). The actual amount of supplement to be offered hay and barley residue was determined after the preliminary adaptation period of two weeks. Every evening a measured amount of grass hay and barley straws was supplied each at 18 h in their respective individual pen. The hay that mainly contained *Andrpogon abyssincus*, *Pennistum*, *Festuca*, and *Trifolium* species was offered un-chopped, while the straw was chopped at the time of threshing. The allowance was increased and set at 400 g/h/d based on the consumption and refusal of feeds during the adaptation period. Leftover was collected and weighed regularly in the next morning at 9:00 am and was bulked on a monthly basis. Daily dry matter intake was determined by subtracting the distinct leftover from what was provided to each animal.

Animal Management.

Menz, Tukur and A×M yearling male lambs were used for the experiment. All sheep were below 12 months of old at the start of the experiment, and were treated with broad-spectrum antihelmentic (albendazole) and Fasinex. Initial weights obtained by weighing for two consecutive days were used to allot sheep to groups so that the mean and standard deviation of group-weights were similar across treatments of the same breeds. Thirty six lambs, were grouped in to three groups (un-supplemented, grazing only; grazing + barley straws and grazing + hay) with initial weight of 20.31±0.90, 20.88±0.90 and 20.23±0.90 kg, respectively, and were allocated to one of the three treatments. The lambs were supplemented in their respective individual pens and lasted for 120 days. Water was supplied *adlib* three times a day and was free of choice during the enclosure time. Body weight was measured fortnightly prior to watering and feeding. Blood samples were collected once a month, before weighing.

Pasture Sampling.

Herbage mass of the grazing area was estimated every week before grazing from randomly selected points of each paddock. The sample was bulked in monthly bases and dried at 65^{o}C for 72 hours until it reached a constant weight and ground to pass through a 1 mm sieve, until analyzed for DM, ash and nitrogen (AOAC, 1990), ADF and NDF (Goreing and Van Soest, 1970) methods

Carcass analysis.

At the end of the experiment, lambs were held off feed and water overnight and slaughtered the next morning after weighing.

Wool samples.

Fleece yield was determined by shearing the sheep at the end of the experiment. Mid side patches of each side of the sheep were clipped from 10x10 cm area prior shearing. The clean weight was determined after scouring in a degreasing solvent, and was dried in a forced draft oven for 24h. Wool staple length and fiber diameter were determined from randomly selected fibers.

Blood analysis.

Blood samples were obtained by jugular puncture on a monthly basis before weighing. Potassium oxalate was used to prevent coagulation of the collected blood. PCV was determined by the microhematocrit method, centrifuging at 1200 rpm for 10 minutes. Acid haematin method was used to determine hemoglobin (Hb) concentration using Sahli- Hellings hemoglobinometer (Fisher Scientific Loughrough, UK).

Experimental Design

A 3x3 factorial arrangement (three feeds: grazing only, grazing + barley and grazing + hay and three breeds: Menz, Tukur and A×M lambs were used to lay down the experiment. Differences between diets, breeds and their interactions of all parameters were considered. Analysis of variance was done using GLM procedures of SAS (1999) statistical packages to test differences among means.

$$Y_{ijk} = \mu+b_i+t_j +bt_{ij}+e_{ijk}$$

Where Y_{ijk} = Means for responsible variables
μ = Overall mean
b_i = Breed effect
t_j = Treatment effect
bt_{ij} = Interaction
e_{ijk} = Error term

RESULTS AND DISCUSIONS

Experiment I Feed Survey in the Central and North-western Parts of Ethiopia

The farming system of the surveyed districts could be defined as smallholder subsistence dominated by rain-fed agriculture. Annual crops that totally rely on animal draught power and family labor with minimal utilization of inputs (improved seed, fertilizer, herbicides and pesticides) and livestock are the major produce.

According to the information gathered, average landholding varies between 1 and 1.5 ha per household, excluding the communal grazing land. The land size is being further diminished as children take their shares when they get matured. How small the farm size might be, it consists of arable land, a living quarter, a variety of trees, a few species of livestock and a garden of vegetables indicating the none specialization of farmers in a single enterprise. The mode of production is mixed farming whereby both crop and livestock productions go side by side. Barley in the highlands; wheat and tef in mid altitudes; and sorghum and maize in the lowlands are the major food crops cultivated in the wet season.

Farmers keep and rear milking cattle, working oxen, goats, sheep, pack animals and poultry mainly as scavengers. Keeping more than one livestock species at a time is a common practice and is considered as a risk aversion mechanism and means of diversification. However, the number and species composition vary based on the wealth status of the farmer. In the lowlands goats and in the extreme highlands sheep are dominant. Sheep are mostly penned at night in the dark unventilated and poorly drained barns in most cases with inadequate floor areas irrespective of their sex. Troughs made of a simple wooden box serve as feed troughs with no protection against spoilage or trampling of feed by younger animals. As stated by the respondents, the number of animals per family is decreasing from time to time due to feed scarcity and shrinking of grazing lands. Shiferaw (1991) and Benin *et al.* (2002) reported a decline of grazing lands due to the expansion of crop cultivation. When farmers were asked which animals they like to own, they preferred to have a pair of oxen, not only for the timely cultivation but also for the social prestige that comes along. Even though the region has immense potential of animal wealth, the level of productivity per animal is low due to a complex set of factors (feed, disease, market, genetics and their interactions). Hence, animals hardly satisfy farmers' needs in generating income and producing of power.

The districts are known for their higher sheep population and fleece utilization. According to the information gathered from the respondents ewes lamb at least once in a year and the first lambing occurs at about 18 months of age. Sheep milk is not consumed at all in the surveyed area, which is in line with the findings of Alemayehu *et al*. (2000a) who further related the case with cultural taboo. Hence, lactation ends naturally when the ewe no longer produces sufficient milk to the lamb. Twining is not common. Unless the farmer intends to introduce a ram of certain merit, usually the ewes and rams run together throughout the year. None of the respondents owned improved rams at the time of the survey. A tradition of selecting the best lamb/s out of the flock as a replacement of older ram/s has been noticed and a few respondents (< 5%) conditioned their ram before mating to serve as many ewes as possible. Ram: ewe ratio is not maintained and number of male sheep in the flock is influenced mainly by the wealth status of the farmer and/or his immediate cash needs.

Sheep are allowed to graze with other livestock species regardless of age and production status. With regard to watering, the respondents stated that the sheep would take care of themselves during the rainy season. However, in the dry season when the majority of the feed comes from dry roughages and water is in a short supply, animals are trekked to the nearby water source or will be provided at home if their number is small.

Based on the information gathered from the total of 596 respondents' crops, animals and animal products are found to be the main cash source of the farming community (Table 5). Since crops cannot be stored indefinitely, whatever is available in excess of the household requirement will be marketed soon after harvest covering about 48% of the total income (Table 5). Money required for daily or weekly expenditure is generated from the sale of animal products. Based on the information gathered about

35% of the annual income of the farmers is generated from the sale of animals and their by-products. It was also observed that farmers have the least tendency to sell animals. However, if forced to do so lambs are the first animal preceded by chicken to be marketed at any time after six months of age, regardless of body weight and condition. In the surveyed areas it was found that livestock are used as a means of saving and capital accumulation. As a result the surveyed districts covering only 8% of the regions' land mass, contains 22% of the sheep, 25% of the horses, 16% of the mules, 13% of the donkeys, 11% of the goats and 9% of the cattle population of the region CSA (2003), signifying the role of livestock in the economy. Gryseels *et al.* (1989) reported that livestock maintain security and investment in the mixed agricultural systems of the central highlands of Ethiopia.

Table 5 Source of family income in percentage

Sources	Number of respondents	Percentage
Crop	286	48
Live animal	137	23
Animal products (butter, cheese, egg…)	30	5
Crop + Live animal	48	8
Crop + Animal products	36	6
Live animal + Animal products	41	7
Crop + Live animal + Animal products	18	3
Total	596	100

Reasons of animal sales with their corresponding percentages are presented in Table 6. The main reasons mentioned for the sales include settling government debts (45 %), covering holiday expenses (30%), overcoming food shortage at time of poor harvest (20%) and the rest (5%) goes to miscellaneous expenses such as school fee, clothing, medical cost and the like (Table 6). the price of live animals varies mainly with the size and condition of the animals and period of the year. The occurrence of drought is one of the main factors that cause fluctuations in the price of live animals in the surveyed districts.

Table 6 Reasons of animal sale in percentage.

Item	Number of respondents	Percentage
Government debt	268	45
Holiday	179	30
Overcoming food shortage	119	20
Miscellaneous	30	5
Total	596	100

From an economic point of view, sheep covers up to 56.72% of the farmers' income from the sub-sector (Table 7). This is in a close agreement with (Awgichew *et al*., 1989; Alemayehu and Fletcher, 1993) who reported that 40-48% of the cash income of the farmer to be generated from the sales of sheep. Butter and cheese also attract a good amount of earnings needed to cover the daily or weekly expenses. Hence, it gets the second highest rank. Farmers who own pack animals obtain continuous cash income by making them available for hiring. The share of poultry was the least not only due to the low contribution, but mainly because most of the respondents were males. Otherwise, chickens and eggs would bring a considerable amount of money to the household, which is needed either for weekly or daily expenditure.

Crop residues and hay are usually offered in the enclosure as a supplement until exhausted. Since the supply is limited, preferential feeding is employed to make maximum use of the resource. Working oxen are supplemented before and after accomplishing a task while dairy cows get supplementation during milking. In response to a question with regard to the sequence of priority of supplementation, 37.65% of the respondents gave priority to working animals, followed by dairy cows 32.94%, sheep 15.29%, and pack animals 14.12% (Table 7). Information gathered indicates that the amount offered greatly influenced by the season and availability and number of animals per household. It is estimated that the amount of supplemental feed ranges between 2-3 kg of hay and 1-2 kg of straw per day. When asked about the strategy of feeding and the mechanism they employ to overcome shortage of feeds, farmers stated that getting adequate feed throughout the year for their stock specifically in the dry season, was a pressing problem. Cereal crop residues are offered to all ruminants when the farmers consider that the available grazing pasture is not adequate to sustain animals. Food legume residues that are well recognized for their nutritional value are given mixed with other feeds by setting priorities. Generally, farmers intend to supplement animals throughout the year adequately. However, they are forced to discriminate due to the limited resource that would not be sufficient for all. According to the information collected, crop residues cover nearly 50% of the dry season feed.

Table 7 Priority of providing supplementation and economic importance in percentage.

Item	Priority of supplementation		Economic significance%	
	Productive	Non productive		
Working oxen	37.65 (1)	20 (3)		*
Milking cows	32.94 (2)	45 (1)	Milk	38.80
Sheep fattening	15.29 (3)	25 (2)	Sheep	56.72
Equines	14.12 (4)	10 (4)	Pack animals	2.99
Poultry	-	-	Chicken	1.49

Number in brackets indicates the priority of supplementation at different period.
* Cannot be expressed in monetary value or percentage.

The problem of overgrazing has resulted in the decrease of pasture species and productivity of communal grazing lands. Figure 5 - 7 demonstrate communal pasture management in dry and wet seasons. Figure 5 depict the condition of overgrazed communally owned grazing lands, in this system all livestock species (regardless of age and species differences) of the locality are allowed to graze together all the time.

Figure 5 Communally owned overgrazed grazing land.

Communally owned and year round grazing lands even in the wet season as depicted in Figure 6, hardly recover as the pasture lacks adequate time for revival. On the contrary, on privately owned grassland; farmers keep their animals away for a certain period of the growing season and are in a better condition Figure 7. The pasture later on be grazed or harvested for hay.

Figure 6 Wet season year round communally grazing land.

Figure 7 Wet season well recovered stock excluded grassland.

The elevation and climatic situation of the districts allow the production of a wide variety of crop species that subsequently provide different amount and quality of feeds. Conservation and feeding of crop residues commences just after threshing and continued until exhausted without any treatment (Van Soest, 1988; Bediye and Fekadu, 2000).

Straws of different crops are stacked separately or in mixture depending up on the farm size and type of crops. Heaps of straws are stacked well to prevent seepage of raindrops and fenced temporarily to deny access to animals. In the region, 3,417,228 tons of crop residues is produced annually (Table 8). The highest production is obtained from cereals of sorghum (729,510 tons) and maize (703,760 tons), while food legume straws' contribution is nearly 10 percent of the total produce. The amount of straws that a farmer collects depends mainly on species and variety of the crop, inputs used (if at all) and intensity of rainfall; and distance from the plot. Farmers do not cultivate crops for their grain yield alone and give emphasis on the residue.

Table 8 Production area, grain and straws' yield by crop (Region total).

Crop	Area ('000 ha)	Yield (tons)	Multipliers	Residue (tons)
Tef	83.81	600,760	1	600,760
Barley	307.60	247,590	1.2[a]	297,108
Wheat	295.97	262,700	0.8[a]	210,160
Finger millet	152.53	157,340	3[a]	472,020
Oats	5.95	45,900	1.5[c]	68,850
Maize	238.41	351,880	2[a]	703,760
Sorghum	360.98	243,170	3[a]	729,510
Food legumes	660.50	335,060	1[b]	335,060
Total	2859.99	22,030,830		3,417,228

Crop residues are calculated using multipliers
a) adapted from Nordbloom (1988)
b) adapted from Yami *et al.* (1991)
c) adapted from Kossila (1988).

The amount of crop residue produced from cereals and legumes in the districts has been estimated to be 0.46 million tons which is 13.53 of the Regions total (Table 9). Thus the highest amount of crop residue is produced in Tenta district (69,190.51) followed by Meket (68,298.56) tons per annum. Crop residues comprise 40-50% of the feed requirements of livestock (Keftassa, 1988), constituting of 45-80% of the cattle (Sanford, 1989) and 40% of the sheep diets (Dicko and Sangare, 1984). During the critical dry periods, crop residues cover up to 83.8% of the feed demand (Belay, 1998).

Table 9 Estimated crop residues production in the surveyed districts (2003).

District	Land mass (km^2)	Cultivated area (ha)[a]	Cereal residue (t)	Legume residue (t)	Total residue (t) [b]
Debark	1,512.22	19,052	24,853.89	6251.80	31,105.69
Wegera	1,862.50	46,700	37,669.13	20,382.20	58,051.33
Farta	1,274.47	39,019	47,935.32	14,625.60	62,560.92
Lay Gayint	1,253.13	22,065	18,498.72	13,515.60	32,014.32
Meket	1,925.01	37,997	50,245.76	18,052.80	68,298.56
Wadela	944.05	24,556	22,822.51	8,885.20	31,707.71
Were Ilu	987.50	31,434	17,403.79	20,191.00	37,594.99
Tenta	1,256.56	35,177	46,694.51	22,496.00	69,190.51
Gera Keya	1,686.88	50,775	20,123.16	14,040.80	34,163.96
Lalo Midir	1,002.5	31,173	21,643.56	14,716.20	36,359.76
Total	13,704.82	337,948	307,890.4	153,157.20	461,047.55

Source a) Obtained from each respected district agricultural bureau.
b) Residue calculated based on crop yield data.

The estimated duration of crop residues feeding along with the livestock population of each district is indicated in Table 10. The total livestock population of the surveyed districts was estimated to be 897,883.5 TLU and 702,630.83 TLU with and without equines, respectively. The length of time during which the residues (tef, wheat, barely, maize, sorghum …) could be available was determined using the number of animals and the amount of crop residue produced in each districts. If the residue is fed uniformly to all livestock, it would last for only a few days from 79 days in Farta and Gera Keya districts to 139 days in Tenta districts. But if the residue is provided to cattle, sheep and goats only the duration is elongated from 99 days in Gera Keya to 178 days in Tenta. Though 2% of body weight is used as the basis to estimate the duration that the feed lasts, in reality the farmers offer below the 2% level and straws last beyond the calculated dates. Taking the total livestock population into consideration, the amount of fibrous residues produced, per TLU is estimated to be 513.48 kg/year, which is below the previous estimation of 600 kg/year (Kossila, 1988). Nevertheless, the estimation is raised to 656.17 kg/year when ruminants (excluding equines) are considered making it comparable to the findings obtained by Kossila (1988).

Table 10 Estimated duration of crop residues per livestock unit by districts.

District	TLU/ district	Duration (days)[a]	Ruminant TLU	Duration (days)[b]
Debark	65,744.28	94.63	49,171.68	126.52
Wegera	101,403.69	114.50	77,753.19	149.32
Lay Gayint	95,243.52	101.03	80,907.37	106.78
Farta	117,182.42	79.14	63,375.67	131.37
Meket	118,867.79	114.92	94,881.29	143.97
Wadela	74,887.40	84.68	56,858.90	111.53
Were Ilu	87,864.71	85.57	66,386.21	113.26
Tenta	99,362.78	139.27	77,683.88	178.13
Gera Keya	86,468.05	79.02	69,018.35	99.00
Lalo Midir	65,195.04	111.54	52,258.14	139.15
Total	897,883.50		702,630.83	

Maintenance level calculated at 2% body weight per day

[a] When all livestock are considered

[b] When only ruminants are considered (excluding equines).

The major feed comes from unimproved natural pasture, crop residues, hay and weeds. Weeds comprise a reasonable amount of the daily ration of ruminants in the wet season. Stacked crop residues become a major feed as the dry season progresses indicating the positive relation between crops and animals. Hay is prepared from natural pasture from September to December and happens to be of low quality. With no change in total dry matter yield of production; Varvikko (1993) found a sharp decrease in CP, (10% in early October to 6% in mid December) with an estimated loss of 250 kg/ha CP which is sufficient to support a crossbred milking cow for one year. None of the respondents cultivates improved pasture, which is in line with the findings of Belay (1998) for the southwestern parts of the country. However, very few farmers mentioned that they planted fodder trees *Sesbania* and *Luceanea* as a fence line. The majority of the farmers do not use agro industrial by-products at all as supplements. Only a few respondents (<1%) who live near the towns and who can afford the price use oil seed cakes as a supplement. Unavailability and high costs are given as the limiting factors indicating an agreement with the findings of Silishi and Bediye (1991). Homemade brewery residues mixed with crop residues are fed to milking cows to enhance palatability and intake.

Another practice mentioned by the respondents is the use of leaves, pods and fruits of various browse trees as a feed *(Acacia* spp., *Sicus sycommorus*, *Cordia* species and others) mixed or alone at the peak of the dry season. Wilting of leaves before offering is a common intervention. Farms of the surveyed area were observed to have scattered trees in their farmlands as a shade. However, the farmers did not deny that the number of trees per farm is decreasing and forest areas diminishing from time to time because browse trees are used for construction (16%), fuel (5%) and other purposes (Table 11). Therefore, maintaining of the existing trees and plantation of new ones should be encouraged both for ecological niche and for their feeding value.

Table 11 Utilization of browse species in the surveyed districts.

Items	Number of respondents	Percent utilization
Feeding	220	37
Construction	95	16
Feeding and construction	179	30
Wood sale	30	5
Feeding + Wood sale	30	5
Construction + Wood sale	24	4
Feeding + Construction + Wood sale	18	3
Total	596	100

Duration of sheep fattening in the survey area lasts usually 3 to 6 months, which is in line with the findings of Alemayehu *et al*. (2002a). Old working oxen and cows take more than 6 months, to bring the animals to attractive marketing conditions. Duration of fattening given by respondents for each district is given in Table 12. Male sheep that are not kept for breeding purposes are sometimes castrated and fed well for longer period with the assumption of fetching a better market price, showing similarity with the findings of (Awgichew *et al*., 1989; Belay, 1998). There is a common belief that states castrated sheep gain weight much quicker than the intact ones and it is common to observe castrated sheep in a village. However, works done by Tiyo *et al*. (1988) did not support the high rate of growth of castrated lambs. According to Awgichew *et al*. (1989), the longer period of fattening may not be related only with accumulation of fat but also with the recovery period of castration shock.

Number of fleece harvests per district is shown in Table 12. Frequent shearing is reported to increase total clean wool production (Bigham, 1974). This might be due to the fact that when fleece is frequently sheared, it will have less chance to hold dust, burr, seeds and plant material as opposed to the less frequent one. Since the survey was not conducted during the time of shearing the fleece yield could not be quantified. However, based on the information given, it was estimated to be 150 to 300 gram per sheep. This yield is relatively lower than that reported for the Menz sheep of the central highlands (Devendra and McLeory, 1982; Lemma *et al.*, 1989; 1993). The difference might be due to the fact that majority of the flock comprised old ewes and lactation is believed to depress wool production (Wheeler *et al.*, 1979). McManus and Reynolds (1976) obtained a heavier greasy fleece from dry ewes as compared with the suckled ones. For each gram increase of milk production in goats, Sahlu *et al.* (1999) reported a decrease of 0.041-0.075 mg/cm^2/day of mohair production. A number of researchers obtained that lactation to suppress wool growth (e.g. McManus and Reynolds, 1976; Langlands, 1977; Corbett, 1979; Reis and Sahlu, 1994). This could be attributed to the competition for nutrients in which the requirements for milk production take priority (Reis and Sahlu, 1994). However, appropriate nutritional management can prevent loss of wool production (Williams and But, 1989).

Table 12 Fattening duration, number of shears per annum and average distance from wool markets.

Districts	Fattening duration (month)		Shears/ annum	Distance from market (hrs)
	sheep	oxen		
Debark	5	***	1	*
Wegera	>3	***	2	*
Lay Gayint	>6	***	2	>4
Farta	6	***	1	*
Meket	2-3	6	1	4
Wadela	6	>6	1	4
Were Ilu	3-6	***	2	3-4
Tenta	3-6	>12	2	**
Gera Keya	>6	>6	2	2-3
Lalo Midir	>6	***	2	5

* Districts, where wool trading is not common

** Districts where the buyer walk around to collect from each household.

*** Less experience in ox fattening

It is believed that there is a potential to improve the livelihood of farmers by increasing the income they obtain from the sale of wool which is highly demanded by artesian and the blanket factory. Crossbreeding local sheep with exotic wool breeds along with improved management could easily bring an impact in quality and quantity as the farmers of the area have traditional skills in fiber production and utilization. It has been reported by Lemma *et al*. (1989) that wool production increased with a rise in exotic blood level. According to Ryder (1993), making fleece improvement through breeding is more economical. As fleece weight is highly correlated with body weight, any move resulting in increased body weight will increase wool production. None of the respondents kept or bred sheep for the fiber value alone as it is considered as a secondary product.

With regard to wool marketing, farmers from Wegera, Debark and Farta districts responded that wool is not marketed in their vicinity. They use it for stuffing of pillow or mattress or will be given free of charge to the needy. This has been confirmed by Ebro *et al*. (1991) who reported the same for Eritrea. Farmers from other districts mentioned that wool has a value and is usually traded off in the nearby markets which are located at four to five hours walking distance on the average (Table 12). Wool is not a perishable product as compared with other animal products. Hence, it could be stored long and marketed at any time. Accordingly, farmers of Lalo Midir and Gera Keya are used to keep fleece until they obtain a better price, while other districts dispose immediately after shearing.

The value of fiber is found to be influenced by color and amount of foreign bodies it contains. It is not uncommon to see color sorting in areas that do have experience in wool bartering. This was mainly due to the fact that white color fleece fetches a better price as the demand is relatively high. No grading system is employed to classify fiber according to its quality or color although weavers are ready to pay a reasonable price for the good one. It was also learned that spun wool fetches a better price than the unprocessed one. Figure 8 and 9 depict the loose and the processed wool markets of Were Ilu. Usually women and children do the processing and women are principally responsible for marketing of the by-product. Traditionally, the fleece is cut using knife/scissors type blades.

Figure 8 Wool market at Were Ilu (open market once in a week).

Figure 9   Processed wool market at Were Ilu (open market once in a week).

Considering the real situations of farmers of the central highlands of Ethiopia, especially the limited land holdings, which is shrinking as times goes, the revenue obtained from sheep and fiber is an additional income that signifies the role of sheep in the community (Table 13). Of all the responding farmers 56%, raise sheep for their monetary value while 8% and 4% appreciate the value of wool, and manure, respectively. Belay (1998) and Alemayehu *et al*. (2000a) also reported that sheep are mainly raised to mitigate financial crises. Wilson (1987) acknowledged the importance of small ruminants in generating income when other sources of income are in short supply.

Table 13 Contribution and purpose of sheep production.

Purpose	Number of respondents	Percentage
Sale for cash	333	56
Home usage (Mutton)	30	5
Wool	48	8
Fuel/fertilization	24	4
Sale for cash + Mutton	30	5
Sale for cash + Wool	65	11
Sale for cash + Fuel	18	3
Mutton + Wool	18	3
Wool + Fuel	6	1
Sale for cash + Mutton + Fuel	12	2
Sale for cash + Mutton +Wool + Fuel	12	2
Total	596	100

Average cost of hay, crop residues, and bricks of common salt in the surveyed districts and their corresponding feeding season is shown in Table 14. According to the informants the price of the salt blocks is almost constant throughout the year, though the price differs from district to district. The price of straws and hay varies based on seasons and becoming relatively lower at time of production. Apart from the provision of common salt, supplementation of other mineral sources is not known at all. Hence, animals rely on forages to satisfy their mineral requirements (McDowell, 1997). The respondents' confirmed that there is a practice of common salt supplementation. Usually, a block of salt will be hanging or put in the feeding troughs. In the absence of the blocks, the loose salt will be dissolved in water and sprinkled on the feed. Salt is supplemented usually in the wet season and is not common during the dry season, unless targeted for specific product. As deficiencies of sodium have been recognized in the region, (Tsegahun *et al*., in press) it is prudent to keep on supplementing animals with common salt. Though salt supplementation is familiar, further research would be necessary to verify whether the current level is adequate or not. Inclusion of other minerals should also have to get due attention.

Table 14 Average cost of supplemental items in sampled areas and their corresponding feeding season.

Items	Average cost (birr)	Season
Salt lick (NaCl) block	10-25	wet
Hay (one load)*	10-15	wet
Straw (one load)*	5-10	dry

*a load on a donkey weighs about 20 to 25 kg.

Purpose of supplementation for each class of animals is given in Table 15. In addition to improving productivity, supplementation serves as a tool to overcome the critical drought period. Farmers are well aware of the value of supplementary feeds and they base their decision on the season and production status of animals. In general, what was learnt from the respondent farmers was that selective feeding is undertaken in the use of conserved and brought in feeds from the farm. Supplementation of ewes with twins and during late gestation period was reported by Hassen *et al*. (2002) for the central highlands of Ethiopia. Agro-industrial by-products such as concentrate mix, flourmill by-products, meat, and bone meal are never used by any of the respondents.

With regard to the time preferred for fattening, all respondents concomitantly agreed that the religious holidays (Christmas and Easter) and Ethiopian New Year attract reasonably higher prices. Although marketing would not be a major problem for those who live near towns with access to all weather roads, the market was not attractive to most of the farmers on ordinary days. Definitely, marketing was mentioned as a problem for those who live in remote rural areas.

Table 15 Purpose of supplementation of domestic animals.

Animal species	Purpose
Oxen	Power
Dairy	Milk
Sheep	Fattening
Pack animals	Over come dry period
Poultry	-

Solutions suggested by the respondent farmers to improve the existing communal pasturelands are given in Table 16. It was learnt that there is no intervention in any of the districts to improve the existing communal grazing lands. Unless it is inundated, year round grazing is a common practice in the communal grazing lands making introduction of improved technologies difficult (Lambourne and Little, 1987; Awgichew *et al*, 1989; Saleem and Tedla, 1995). On the contrary, how small it might be a private grazing area is managed in a different way. When farmers were asked to suggest methods of pasture improvement, low stocking rate and using of graded animals (70%) and improved forages (15%) were forwarded as the best options followed by use of rotational grazing (5%), purchasing of additional feeds (5%), application of manure (3%), and fencing (2%; Table 16).

Table 16 Farmers attitude towards addressing communal grazing land problems

Suggested solutions	Number of respondents	Percentage
Use of cultivated pasture	89	15
Lower stalking rate	268	45
Purchase of additional feeds	30	5
Use of improved animal breeds	149	25
Manure/fertilizing	18	3
Fencing	12	2
Rotational grazing	30	5
Total	596	100

Information on diseases was obtained through discussion and it was learnt that there are different types of endemic diseases in the surveyed districts. The economic loss due to diseases and parasites was reported to be high by the respondents even though it could not be quantified at the time of the study. Awgichew *et al*. (1989) estimated a national mortality average of 10-20% for sheep and goats, while Alemayehu and Fletcher (1993) put an estimation of 23% for sheep and 25% for goats for the central highlands. Farmers usually depend on local healers to treat sick animals, and decide to seek veterinary advice when their attempts fail. Reasons given for such practice were mainly, either distance of the clinics (usually at district level) or the presumed high cost of medication. Modern treatments and medicaments are available only from the veterinary clinics of MoA and to a lesser extent, open markets. Belay (1998) reported the same sources for south western parts of the country. The community listed anthrax, parasites, pasteurellosis, black leg and sheep pox as the major important diseases which hinder the livestock sub sector jeopardizing production and incurring medicinal cost and animal losses. This is in agreement with the report of (Gryseels *et al*., 1989; Wilson *et al*., 1985; Tolera, 1990). Based on the information obtained from the respondents, the impact of livestock diseases is being reduced through time because of a good follow up of the MoA. The respondents consider losses due to predators, accidents, theft, and starvation as a minor case.

The respondents agree that lamb mortality is high between birth and weaning age, which is in line with Lemma *et al*. (1993) who reported that 75% of mortality occurred before weaning. All respondents concomitantly agreed that mortality rate and age of sheep are negatively correlated. It was reported that losses of lambs is high when lambing occurred at the peak of the dry period. In the traditional sheep husbandry system lambing could occur at any season of the year as ewes and rams run together in the same pasture (Tolera, 1990; Hassen *et al*., 2002). Loss of sheep is the major threat to the industry, as the number of surviving lambs that reach marketing age is a determining factor for the success or failure of the enterprise. In any sheep enterprise, the most important factor affecting profitability is its reproductive level (Schoenian and Buffering, 1990) which is best measured by the number of lambs marketed upon which income is based.

Extension service rendered in the surveyed area mainly focuses on crop production with little emphasis on livestock production. None of the respondents reported the presence of extension services for fiber production and processing, with the exception of Gera Keya district. Credit services similar to that of extension also targets crop production. No credit system is organized in any of the districts either to purchase wool or loom. The source of credit in the surveyed districts mainly comes from government treasures.

The risk of production failure and relatively low prices of agricultural products soon after harvest made respondents to refrain from using credit system to promote their production. In all the districts all agricultural products are sold in the near by local markets. Market accessibility and stability schemes should be introduced and organized systematically to benefit all stakeholders. In the absence of proper marketing channel, farmers are heavily dependent on local markets (Galal, 1982). Prices paid by itinerant buyers to farmers are low and profits accrue to intermediaries rather than the real producer. This situation highly discourages farmers from using new technologies to improve productivity.

EXPERIMENT II Chemical and Macro Mineral Comparison of Feed Stuffs Collected from the Central and North-western Parts of Ethiopia.

Mean values of the chemical and macro minerals of feeds collected from the central and northwestern parts of Ethiopia are given in Table 17. Out of the collected feed samples, 47.73 percent were found to contain less than the critical CP level of 7 percent. Out of the 39 crop residues, none of them contained a CP value of 7%. The value of CP in the crop residues ranges from 2.57 of *Triticum aestivium* to 3.76 of *Hoerdeum vulgare*. High CP values are obtained from oil seed cakes that range from 24.94 mixtures of *G. abyssinica* and *C. abyssinica* to 35.85 in *G. abyssinca* and *Brasica* species. Out of the sampled feeds, 29.55% contained NDF above 60% and all were cereal straws. Reed and Goe (1989) found 70% NDF in cereal straws, which is in close agreement with the current findings of 64.83 of barley and 67.27% of tef. With regard to *in situ*, out of the 176 sampled feeds only 15.34% had a digestibility of above 50%. If the value given by McDowell (1988) for apparent digestibility (42-45) is taken as a minimum requirement to sustain maintenance needs 26.14% of the feeds would fall in this category. The *in situ* value is found to range from 28.90 for *C. africana* to 89.69 for *B. vulgaries*.

Out of the total feeds analyzed, only 4.55% were found to be deficient in Ca; with the range of 0.13 (wheat/barley mixed straws) to 4.99% (*Sesbania sesban)*. Browse species, improved forages, straws of food legumes and grazing pasture do fulfill the minimum level of Ca (Table 17). The Ca values found in this study were found to be higher than the reports by Khalili *et al*. (1993) and Geleti *et al*. (2001) for the central and western highlands of Ethiopia, respectively and were comparable with that of T/Debessai (1984) reported for the eastern part of the country. The result of Kabaija and Little (1988) was comparable for browse species and found to be less for hay and crop residues collected from southern and central parts of the country. Ogebe *et al*. (1995) reported a similar Ca value for tree leaves and crop wastes. However, the value reported by the same authors for grass was below the results obtained in this study. This disparity could be due to the difference between species (Long *et al*., 1970; 1972), as the samples

Table 17 Chemical and macro mineral content of different feeds (percentage dry matter basis).

Scientific/Common name	DM%	Ash	CP	ADF	NDF	Hemicellulose	*In situ*	Ca	P	Mg	Na	K
Indigenous browse species												
Erica aroborea	92.07	5.88	7.67	39.27	43.83	4.56	34.40	0.47	0.11	0.19	0.014	0.61
Hypericum lanceolatum	89.18	4.16	13.43	40.27	46.08	5.81	38.20	0.64	0.21	0.20	0.005	0.98
Zizyphus spina	89.34	7.99	12.37	30.41	36.85	6.45	40.58	2.21	0.24	0.30	0.003	1.09
Cordia Africana	88.14	16.19	16.53	56.57	68.43	11.86	28.90	3.34	0.29	0.67	0.005	3.03
Sicus sycommorus	88.16	28.46	8.89	38.59	47.19	8.60	33.35	4.06	0.22	0.66	0.005	1.18
Euclea spp.	89.26	8.02	12.02	42.26	53.44	11.18	30.70	2.01	0.21	0.56	0.003	1.51
Improved grass species												
Phalaris spp.	89.82	11.07	8.14	29.98	52.07	22.09	43.55	0.45	0.19	0.18	0.239	2.22
Avena sativa	89.23	6.47	5.87	33.41	49.38	15.97	49.66	0.37	0.13	0.14	0.047	1.72
Improved legume species												
Vicia spp	89.48	12.21	17.00	33.15	39.65	6.49	41.23	2.19	0.21	0.40	0.041	2.57
Sesbaina sesban	89.51	14.70	28.10	14.49	16.67	2.17	44.36	4.99	0.34	0.47	0.355	1.24
Chamaecytisus palmensis	89.93	6.10	17.85	26.55	35.20	8.65	61.74	1.28	0.18	0.40	0.100	1.22
Root crops												
Beta vulgaries	94.46	6.35	2.74	6.06	12.55	6.49	89.69	0.43	0.09	0.30	0.348	2.18

Table 17 (cont'd)

Scientific/Common name	DM%	Ash	CP	ADF	NDF	Hemicellulose	*In situ*	Ca	P	Mg	Na	K
Food legume straws												
Pisum sativum	90.69	7.22	4.98	53.76	59.82	6.06	45.23	1.13	0.12	0.17	0.027	2.13
Vicia faba	90.26	11.60	6.66	44.21	51.32	7.11	51.68	1.43	0.18	0.19	0.328	2.53
Lens clinaris	90.44	9.54	6.79	39.77	48.56	8.80	61.07	1.55	0.12	0.26	0.012	1.86
V. faba+ P. sativum	90.65	6.65	3.90	60.22	68.42	8.20	31.74	3.90	0.12	0.08	0.159	1.18
Trigonella foenum-graecum	90.07	8.81	5.55	46.38	53.90	7.51	50.81	1.97	0.06	0.16	0.110	1.62
Cereal crop straws												
Hordeum vulgare	91.00	8.62	3.76	46.61	64.83	18.22	35.74	0.43	0.17	0.09	0.414	1.56
Triticum aestivum	91.44	9.67	2.57	46.35	65.03	18.68	30.97	0.30	0.09	0.07	0.025	1.15
Eragrostis tef	91.33	7.01	3.44	40.42	67.27	26.85	34.08	0.37	0.13	0.12	0.007	1.07
H .vulgare + T. aestivum	90.30	4.81	6.88	26.49	44.94	18.46	48.74	0.13	0.23	0.12	0.053	0.85
Eleusin coracana	91.20	9.91	3.69	36.60	62.58	25.98	33.67	1.03	0.28	0.10	0.003	1.5
Flour by-products												
V. faba+ P. sativum hull	90.25	4.63	9.09	48.90	53.30	4.40	35.15	0.51	0.15	0.18	0.033	
Lens clinaris	89.58	4.64	18.94	23.35	31.60	8.27	62.12	0.34	0.40	0.20	0.020	0.76
V. faba hull	90.88	3.45	12.96	51.18	55.48	3.70	46.75	0.50	0.29	0.12	0.005	0.72
P. sativum hull	89.75	4.26	17.12	34.25	41.54	7.29	52.91	0.41	0.37	0.13	0.003	1.13
Mixed grains	90.26	12.04	10.23	17.18	35.35	18.17	66.01	0.30	0.34	0.16	0.056	0.80
Korefe (home made brewery residue)	90.67	6.42	11.14	38.30	66.09	27.79	30.70	0.39	0.34	0.17	0.014	0.43

Table 17 (cont'd)

Scientific/Common name	DM%	Ash	CP	ADF	NDF	Hemicellulose	*In situ*	Ca	P	Mg	Na	K
Oil seed crushing plant residue												
Guizotia abyssinica	91.11	11.23	30.52	26.53	30.61	4.08	64.57	0.92	1.78	0.60	0.002	1.71
G. abyssinica + *Carthamus abyssinica*	91.47	8.34	24.94	37.79	42.19	4.40	55.58	0.58	1.31	0.26	0.002	1.13
G. abyssinica + *Brassica* spp.	91.16	10.07	35.85	20.20	24.72	4.52	60.00	1.01	1.39	0.72	0.003	1.56
Hay (native pasture, mixed)	90.60	9.21	7.53	38.31	59.35	21.04	41.92	0.71	0.23	0.17	0.033	1.76
Native pasture												
Andropogon, Trifolium, pennistum	90.01	9.60	8.60	36.53	54.67	18.14	41.40	0.82	0.22	0.31	0.038	1.94
Thymus serrulatus	89.33	7.33	8.80	49.09	62.00	12.91	39.90	1.41	0.18	0.24	0.010	1.58
Festuca abyssinica	90.99	8.71	5.58	41.32	63.49	22.17	29.22	0.51	0.15	0.11	0.008	0.84
Hypernia spp.	90.70	7.06	4.81	44.54	64.36	19.82	32.86	0.47	0.13	0.24	0.004	1.11
Natural pasture (mixed)	90.94	9.16	6.06	41.91	61.53	19.62	36.16	0.67	0.15	0.18	0.070	1.76

were not of the same type. The K values of hay, crop residues and browse species reported by T/Debessai (1984), Kabaija and Little (1988) and Bediye and Fekadu (2000) were comparable with the current findings (Table 17). The phosphorus level was found to be sufficient only in 11% of the feeds analyzed, of which the majority were by-products. The range of P goes from 0.06 in *Trigonella foenum-graecum* to 1.78 in *G. abyssinica* (Table 17). Thirty two percent of the tested feeds were found to be deficient in Mg content with a range of 0.07% (wheat straw) to 0.72% (mixture of *G. abyssinica* and *Carthamus abyssinica* cakes). Though the value of Na obtained in this finding was found to be comparable with that of Kabija and Little (1988) given for hay and crop residues out of the mineral analyzed Na was found to be the most deficient mineral. On the contrary, K concentration was found to be adequate in most of the feeds (Table 17).

A large variation in digestibility was seen among the feed types (Table 18). The *in situ* value of food legume straws (50.82±8.59), improved forages (50.48±13.06), and by-products (47.92±18.89) were found to be better than their counterparts did. When the types of feeds were rated based on their grouping in terms of digestibility, the order was cereal straws (tef, barley, wheat) < browse species (indigenous trees) < grazing pasture < hay (natural pasture) < by-products (flour and oil seed crushing plants) < improved forages < food legumes (faba bean, field pea, chick pea, lentil). The lowest value in cereal crop residues (tef, wheat and barley) might be related with the pronounced over maturity, high cell wall contents and over all senesced materials. The low digestibility of indigenous browse species might be attributed to the less emphasis given so far to improve their productivity on top of the presence of anti-nutritional elements. Alemayehu *et al*. (2000b) obtained low *in situ* value in browse species as compared to grazing pasture, though the browses had better CP than the grazing pasture, which is in line with the current findings (Table 18).

Feeds having 50-55 percent digestibility, supply sufficient energy to meet the maintenance needs of sheep Pearce (1982) and draught animals (Reed and Goe, 1989). Accordingly, improved forages (50.48±13.06) and food legume straws

(50.82±8.59) satisfy the marginal requirement given by Pearce (1982). By-products (47.92±18.89) and native pasture hay (42.50±5.61) approached the level while the digestibilities of other feeds (cereal straws, browse, and grazing pasture) were found to be far below the given mark. The quantity of digestible energy consumed is the ultimate determinant of the level of animal production (Little, 1987).

The NDF content of cereal crop residues (65.48±4.29), hay (59.03±9.13), and grazing pasture (58.43±8.41) was high (Table 18) as compared to cultivated forages (40.86±12.52) and browse species (48.13±11.32). The high NDF value indicates that these feed resources are poor in quality and contain mainly structural components, which is accountable for the low digestion, low rate of passage, and limited voluntary intake (McDowell, 1988). The values of NDF obtained for the dry forages (hay and cereal crop residues) and green feeds (browse and improved forages) were in agreement with that of (Yami, 1981; Carangal and Calub, 1987; Bediye and Silishi, 1989a; Said and Tolera, 1991).

Table 18 Chemical composition and *in situ* of major feeds of the surveyed districts (% DM basis).

Feed type	DM	Ash	CP	ADF	NDF	Hemicellulose	*In situ*
Grazing pasture	90.37±1.04	8.75±2.54	7.22±3.60	39.86±8.33	58.43±8.41	18.57±6.06	37.87±7.52
Hay	90.58±0.51	9.48±2.20	7.56±2.68	38.95±9.96	59.03±9.13	20.75±8.17	42.50±5.61
Browse species	89.58±1.33	9.52±7.10	11.68±3.15	40.17±10.87	48.13±11.32	7.97±3.97	34.20±3.77
Cereal crop residue	91.19±0.58	8.52±2.22	3.33±0.98	45.0±93.97	65.48±4.29	20.39±5.95	34.07±4.05
Improved forages	89.79±1.19	9.18±3.91	13.10±7.78	29.25±9.16	40.86±12.52	11.60±7.83	50.48±13.06
By-products	90.56±0.70	7.72±3.61	16.42±9.22	32.01±12.50	47.17±19.04	16.23±11.55	47.92±18.89
Food legume residue	90.36±0.57	8.48±5.27	8.54±6.10	44.51±10.49	51.45±9.81	6.94±3.00	50.82±8.59

The lowest DM value obtained from browse species (89.58±1.33) and improved forages (89.79±1.19) as given in Table 19 were found to be in line with the findings of (Yami, 1981; Bediye and Silishi, 1989b). Low DM values of these green feeds may recall the provision of feeds with high dry matter before offering these feeds for efficient utilization. With regard to the DM of crop residues, the value (91.19±0.58) was comparable with that of Said and Tolera (1991) given for wheat straws. The DM of by-products (90.56±0.70) was within the range given by Bediye and Silishi, (1989a). The ash value for crop residues 8.52±2.22 (Table 18) was comparable with the mean value reported by Said and Tolera (1991). The ash value of by-products (7.72±3.61) was lower than those reported by (Bediye and Silishi, 1989a) and was higher than the values given for oil seed cakes (Bediye and Silishi, 1989b).

The CP content of the feeds varied between 3.33±0.98 in cereal crop residues to 16.42±9.22 in by-products (Table 18). By-products contained the highest CP (16.42±9.22) followed by improved forages (13.10±7.78) and browse species (11.68±3.15). Crop residues contained the least value (3.33) which is below the minimum threshold level of 7% required to optimize rumen fermentation and maintain a positive N balance (Minson, 1971; Van Soest, 1982). The CP value obtained for cereal crop residues is in agreement with the findings of (Yami, 1981; Carangal and Calub, 1987; Kabaija and Little, 1988; Said and Tolera, 1991; Schulthess *et al*., 1995; Bediye and Fekadu, 2000) who reported a low level of CP for various crop residues. Hence, animals kept exclusively on cereal straws cannot maintain their nitrogen balance because of the low N and high cell wall content and slow digestion (Bediye and Fekadu, 2000) resulting in low animal production if fed alone. To achieve maximum performance from such feeds, it is imperative to include slowly degraded nitrogen source/s as a protein supplement. Though cereal crop residues are often deficient in CP, Powell (1986) stated that at the same time of the year the levels of protein consumed by livestock from crop residues are 2-3 times higher than that available from natural grazing. Crop residues are widely used to augment feed scarcity; and their utilization is governed by the availability of other feeds, farm size, cropping season, and distance from the homestead, storage facilities, labor, and purpose of livestock production (Carangal and Calub, 1987).

The mean value of CP of the food legumes (8.54±6.10) was comparable with that of Carangal and Calub (1987). Straws of such legumes could contribute a lot in enhancing the feeding value of cereal residues in the dry season, as both are available simultaneously in the farm where other sources are in short supply. Jayasuriya (1984) recommends the appropriateness of legumes as a supplement for African farmers. Though their availability is very limited, browse species and cultivated forages contain (Table 18) a higher level of CP (11.68±3.15 and 13.10±7.78, respectively). They are mainly used selectively for lactating cows and fattening animals to optimize production and alleviate protein shortages (D'Mello, 1992). Hence, plantation and protection of browse species should go side by side with the introduction and dissemination of improved forages. Mosi and Butterworth (1985) confrimed that cultivated forage crops could increase the nutritive value of crop residues as strong alkali could do so. The high CP value in oil seed cakes is advanageous to use them as protein supplement, as they are accesible from oil extraction plants of the near by towns.

Macro mineral status of different feed resources based on the season is given in Table 19. As shown in the table, there is a distinct variation in mineral concentration of the feeds between the wet and dry seasons. The general trend indicates that most of the feeds collected in the dry season fall in the category of deficient and borderline than samples of the wet season. As shown in the table, out of the total feeds collected in the dry season, 7.45% were deficient in Ca, 53.19% in P, 56.38% in Mg, 95.38% in Na and 12.77% in K. The corresponding values of the wet season feed samples were 1.22%, 34.15%, 6.10%, 83.78%, and 3.66% for Ca, P, Mg, Na and K respectively (Table 19).

Geleti *et al.* (2001) obtained a higher level of Ca in the wet season than in the dry season being consistent with this study, where the percentage of feeds that were found to be deficient was low (1.22%) in the wet season as compared with that of the dry season (7.45%). T/Debessai (1984) also reported that out of the 86 green feeds analyzed during the wet season for Ca, none of them contained below the critical level. This finding is in agreement with the current study in which 99% of the wet season feeds meet the minimum required level of Ca given by McDowell (1997) for sheep (Table 19). Since several factors affect the bio-availability of Ca such as age, vitamin D level, amount of calcium fed and calcium status of animal; Peeler (1972) suggested that the Ca content of a feed to be evaluated based on the amount absorbed rather than on its analytical content.

Table 19 Status of macro minerals of feeds sampled in the two seasons.

Minerals	Requirement %	Dry Season			Wet Season		
		Defic	B.line	Suffic	Defic	B.line	Suffic
Ca	0.20-0.82	7.45	68.09	24.45	1.22	60.98	37.80
P	0.16-0.38	53.19	37.23	9.57	34.15	53.66	12.20
Mg	0.12-0.18	56.38	28.72	14.89	6.10	14.63	79.27
Na	0.50-0.80	95.38	3.08	1.54	83.78	9.01	7.21
K	0.09-0.18	12.77	13.83	73.40	3.66	7.32	89.02

Defic (deficient), B. line (borderline), Suffic (sufficient).

Macro mineral status of the feeds collected from the three-altitudinal range is given in Table 20. Calcium was found to be deficient only in 6.06% of the feeds collected from the higher altitude areas. With regard to P concentration, of the total sampled feeds, 40% of the low, altitudes 54.55% of the mid altitudes and 42.11% of the high altitude feeds were found to be deficient in P concentration. Livestock of the mid altitudes are more liable to P deficiencies as P was found to be deficient in 54.55% of the feeds as compared with the other altitudinal ranges. Magnesium was found to be deficient in 10% of the lower altitudes, 36.36% of the mid altitudes and 32.56% of the higher altitudes. Sodium was found to be deficient 100% in the lower altitudes and in 96.97% of the mid altitude and 84.96% of the higher altitudes. To curb this phenomenon, the tradition of common salt supplementation should be encouraged at large, until a better solution is developed. Potassium content of the feeds was found to be in good shape when compared with other minerals (Table 19).

Table 20 Macro mineral status of feed resources in the three altitudinal ranges%[1].

Minerals	Requirement%	Higher altitudinal range			Mid altitudinal range			Low altitudinal range		
		Deficient	Borderline	Sufficient	Deficient	Borderline	Sufficient	Deficient	Borderline	Sufficient
Ca	0.20-0.82	6.06	65.15	28.79	27.27	72.73	0.00	0.00	30.00	70.00
P	0.16-0.38	42.11	48.12	9.77	54.55	42.42	3.03	40.00	60.00	0.00
Mg	0.12-0.18	32.56	24.81	42.64	36.36	27.27	36.36	10.00	10.00	80.00
Na	0.09-0.18	84.96	8.27	6.77	96.97	3.03	0.00	100.00	0.00	0.00
K	0.50-0.80	9.77	12.78	37.44	3.03	3.03	93.94	0.00	30.00	70.00

[1] Percentage of feed resources in the three altitudinal ranges that are deficient, border line or sufficient in macro minerals

Table 21 indicates the percentage of different feed types that were deficient, borderline, or sufficient in macro mineral concentration. Accordingly, grazing pasture was found to be deficient by 51.22% (P), 17.07% (Mg), 9.76% (K), and 87.80% (Na). Sodium was found to be the most deficient macro mineral in most all feed types, and was found to be deficient in browse species (100%), by-products (96.15%), and cereal straws (95.24%) and hay (95%). This is in agreement with the findings of (Kemp and Guerink, 1978; Tolera, 1990; McDowell *et al.*, 1983) who reported Na as the most deficient mineral and suggest its supplementation to alleviate the problem. The existing tradition of Na supplementation should be encouraged at all.

All sampled browse species fulfilled the minimum requirement of Ca set by McDowell (1997) for sheep. The Ca value obtained by Kabaija and Little (1988) for hay, crop residues and browse species was comparable with these finding. The deficiency of P in by-products was found to be 7.69% while the deficiency of P varied between from 15% (cereals) to 86.67% (food legume straws). This indicates that by-products contain adequate level of P, which enables the feed to be categorized as a P supplement, which is in agreement with that of Kabaija and Little (1988). Whenever by-products are used as animal feeds, attention should be given to correct K as these materials are deficient in K (McDowell, 1997).

Cereal straws were found to be deficient in P, Na, and Mg by 71.43, 95.24, and 76.19%, respectively. Comparatively less percentage (66.67%) of straws of food legume were categorized as Na deficient compared with other feed types where the deficiency ranges from 87.80% in grazed pasture to 100% in browse species (Table 21). Among the feed types, straws of cereal crops and food legume were found to be low in their P content. The P level should get special consideration whenever straws constitute the bulk of the ration. The Mg value obtained for grazing pasture was in line with that of Kabaija and Little (1988) and Geleti *et al*. (2001) and is lower than that given by T/Debessai (1984) and Bediye and Fekadu (2000) for forages, cereal straws and browse species. Although 73.91% and 47.83% of the improved forages were found to be deficient in Na and P, respectively; none of them contained low levels of Ca and K than suggested by McDowell (1997) for sheep.

Table 21 Macro mineral status of different feed types in the study area %.

Feed types	Calcium			Phosphorus			Magnesium			Sodium			Potassium		
	Deficient	Border line	Sufficient	Deficient	Border line	Sufficient	Deficient	Border line	Sufficient	Deficient	Border line	Sufficient	Deficient	Border line	Sufficient
Grazing pasture	0.0	70.73	29.27	51.22	43.90	4.88	17.07	14.63	68.29	87.80	7.32	4.88	9.76	2.44	87.80
Hay	20.00	80.00	0.0	15.00	80.00	5.00	25.00	35.00	40.00	95.00	5.00	0.0	0.0	10.00	90.00
Cereal straws	9.52	88.10	2.38	71.43	26.19	2.38	76.19	23.81	0.0	95.24	2.38	2.38	0.0	16.67	83.33
Food legume	0.0	13.33	86.67	86.67	13.33	0.0	26.67	33.33	40.00	66.67	26.67	6.67	0.0	6.67	93.33
By-products	15.38	69.20	15.38	7.69	38.46	53.85	19.23	30.77	50.00	96.15	3.85	0.0	34.61	23.08	42.30
Browse	0.0	36.36	63.64	27.27	72.73	0.0	18.18	81.82	0.0	100.0	0.0	0.0	9.09	27.27	63.64
Improved forages	0.0	47.83	52.17	47.83	52.17	0.0	8.70	26.09	65.22	73.91	8.70	17.39	0.0	4.35	95.65

Experiment III The Effect of Supplementation of *Lotus corniculatus* Hay on Body and Fleece Weight of Sheep Grazing Natural Pasture in Dry Season

The chemical composition of *L. corniculatus* and the grazing pasture is given in Table 22. The available pasture was either dead/dormant and was low in its chemical constituents. As indicated in the table, the grazing pasture had lower CP and higher NDF, ADF and hemicellulose content than the lotus hay (Table 22). There was no refusal of lotus hay throughout the experimental period.

Table 22 Chemical composition of grazing pasture and Lotus hay.

	Pasture	Lotus
DM%	91.23	90.06
Chemical composition, % of DM		
CP	5.91	13.94
NDF	69.22	38.78
ADF	47.78	27.61
Hemicellulose	21.44	11.71
Ash	8.75	9.39

The weight gain and carcass measurements obtained as a result of the feeding treatment is given in Table 23. The levels had effects on body weight and some carcass traits. The un-supplemented group sustained a weight gain of 1.66 kg ($p<0.0001$) during the experimental period while supplementing of lotus at 100, 200, and 400 g per day resulted a live weight gain of 3.49, 5.12 and 5.55 kg respectively (Table 23). The live weight change gram per day (g/d) reported by Said and Tolera (1993) for the herbaceous legumes of *Desmodium intortum*, *Stylosanthes guianensis* and *Macrotyloma axillare* at different feeding levels were lower than the current findings indicating the potential of lotus to be used as an alternate forage legumes, where the environment limits production of a wide range of forage species. Weight gains of sheep on the higher levels of 200 and 400 g/h/d were similar and significantly higher ($p<0.0001$) than the un-supplemented group and from those receiving 100 g lotus per head per day; indicating a better response to lotus supplementation. Douglas *et al*. (1995) also obtained a higher live weight gain from lotus as opposed to lucerne or lucerne and lotus mixed pasture. However, the high level of lotus did not produce a better dressing percentage among treatments.

No significant difference was observed ($p>0.05$) among the 200 and 400 g/h/d treatment groups and between the 100 g/h/d and the un-supplemented group in final weight (Table 23). The weight gain from 200 and 400 g was higher than that of the un-supplemented group by 30% and is consistent with the oats/vetch studies of (Lemma, 1995). The weight gain 13.85 g/h/d by the un-supplemented lambs (grazing only) was by far less than what Lemma *et al*. (1991) found during the late rainy to early dry months, which might be related with pasture availability and quality.

Table 23 Different levels of *L. corniculatus* on body weight and carcass characteristics of three sheep breeds

Item	Lotus hay (g)				SEM
	0	100	200	400	
Initial wt (kg)	20.92	20.67	19.63	20.29	0.80
Final weight (kg)	22.29^{b}	23.76^{b}	25.54^{a}	26.48^{a}	0.52
Weight gain (kg)	1.66^{c}	3.49^{b}	5.12^{a}	5.55^{a}	0.32
Empty body wt (kg)	20.65^{c}	21.42^{bc}	23.22^{ab}	23.87^{a}	0.85
ADG (g)	13.85^{c}	29.09^{b}	42.74^{a}	46.28^{a}	2.67
Hot carcass wt (kg)	8.68^{b}	9.15^{b}	9.66^{ab}	10.48^{a}	0.42
Dressing (%)	42.02	42.73	41.40	43.93	0.86
Viscera full (kg)	3.99	4.30	4.24	4.14	0.31
Viscera empty (g)	535.56	510.00	523.75	564.17	22.09
Tail wt (g)	262.50^{c}	373.33^{bc}	421.67^{ab}	498.33^{a}	42.56

^{abc} means in the same row with different superscripts are different ($p<0.05$).

The body weight and carcass characteristics of lambs fed with different levels of lotus hay are given in Table 24. The A×M sheep performed better ($p<0.0001$) in both weight gain and ADG than Menz and Tukur sheep. Among the breeds the Tukur sheep was the least ($p<0.0001$) in total weight gain (2.31 kg) and average daily gain (ADG) (19.22 g) compared to A×M and Menz sheep ($p<0.05$). Lemma *et al.* (1991) also obtained a higher average daily gain of 68 and 118 g/day for Menz and A×M sheep fed with concentrates for 200 days with concentrates indicating the potential of the breeds under better management. No significant difference ($p>0.05$) was noted in the viscera empty weight among the breeds (Table 24). Dressing percentage of Menz and Tukur lambs was significantly higher ($p<0.001$) than that of A×M breeds; and there was no difference between Tukur and Menz lambs ($p>0.001$). No interaction was observed in any of the measured parameters.

Table 24 Body weight and carcass characteristics of the three lamb breeds.

Characteristics	Sheep breeds			SEM
	A×M	Menz	Tukur	
Initial weight (kg)	19.78	20.25	21.09	0.69
Final weight (kg)	25.86^{a}	24.99^{a}	22.70^{b}	0.45
Weight gain (kg)	5.44^{a}	4.13^{b}	2.31^{c}	0.28
Empty body wt (kg)	23.32	23.04	21.50	0.73
ADG (g)	45.30^{a}	34.45^{b}	19.22^{c}	2.31
Hot carcass wt (kg)	8.95^{b}	10.29^{a}	9.24^{ab}	0.36
Dressing (%)	40.05^{b}	44.62^{a}	42.96^{a}	0.74
Viscera full (kg)	5.04^{a}	3.71^{b}	3.75^{b}	0.26
Viscera empty (g)	543.75	546.88	509.48	19.14
Tail weight (g)	350.00^{b}	459.38^{a}	357.50^{ab}	36.86

^{ab} Means in the same row with different superscripts are different ($p<0.05$).

Both treatment and breed differences did not produce any significant difference ($p>0.05$) in any of the non-carcass traits (Table 25 and 26).

Table 25 Non-carcass compositions of lambs supplemented with different levels of *L. corniculatus* hay.

Item	Lotus level (g)				SEM
	0	100	200	400	
Head (kg)	1.64	1.69	1.82	1.92	0.85
Feet (g)	530.00	506.83	495.00	540.00	23.61
Skin (kg)	2.29	2.25	2.36	2.51	0.11
Heart (g)	113.33	138.33	100.00	100.83	15.53
Kidney (g)	62.50	57.50	62.50	63.33	4.95
Lung and trachea (g)	401.67	382.50	379.17	441.67	27.49
Spleen g)	51.67	47.50	55.00	54.17	5.49
Liver (g)	308.33	261.67	315.00	313.33	21.73

Table 26 Non-carcass parameters of the three sheep breeds.

Item	Sheep breeds			SEM
	A×M	Menz	Tukur	
Head (kg)	1.78	1.80	1.73	0.07
Feet (g)	539.50	482.50	531.88	20.50
Skin (kg)	2.31	2.43	3.75	0.10
Heart (g)	126.88	96.88	115.63	13.45
Kidney (g)	27.81	31.88	28.44	4.14
Lung and trachea (g)	436.88	389.38	377.50	23.81
Spleen (g)	51.25	50.63	54.38	4.75
Liver (g)	307.50	301.25	290.00	18.82

The author is not aware of any published result of a full-fledged experiment that indicates amount and quality of fiber production from the indigenous sheep breeds of Ethiopia, except the few observations of (Devendra and McLeroy, 1982; Galal, 1983; Lemma *et al*., 1989; 1991). Hence, this study happens to be the first of its kind in Ethiopia by reporting results of fleece yield with some of its characteristics.

Fleece characteristics of sheep were not influenced by lotus supplementation (Table 27) which is in line with (Douglas *et al*., 1995; Waghorn and Shelton, 1997) who found no difference in wool length of sheep that graze/supplemented with *L. corniculatus*; and Walz *et al*. (1998) who obtained no difference by supplementing fish meal or sodium bentonite. Messenger *et al*. (1971), Entwistle and Knights (1974), Barry and Drew (1978), Wheeler *et al*. (1979), Hawker and Thompson (1987) as well did not find treatment effects either on greasy wool production or fiber characteristics, which is in line with this finding. Min *et al*. (1998) also did not obtain any effect of treatment on fiber diameter, length, bulk density and wool resilience though they found a reaction in wool production. Although the level of treatment did not have effect ($p>0.05$) on any of the fleece characteristics studied, fleece yield was observed to increase as the levels of lotus supplementation increased. One explanation for the no response to the levels of supplementation is that nutrient demands for growth are greater than for wool growth (Black and Reis, 1979) as cited by (Walz *et al*., 1998). In the current experiment, the young lambs may have partitioned nutrients towards body growth rather than to wool growth largely than adult sheep do (Walz *et al*., 1998). However, the trend indicates that total greasy and clean fleece production increased as the level of supplementation increased. Fleece production of lambs in the un-supplemented group was the least followed by those in the 100 g whereas those in the levels of 200 and 400 g/h/d were highest. With regard to fleece length and diameter, there was no clear indication of either increasing or decreasing as the level changes.

Table 27 Effect of different levels of lotus hay on fleece characteristics of lambs.

Characteristics	Lotus level (g)				SEM
	0	100	200	400	
Greasy weight (g)	722.61	838.36	892.88	873.38	70.05
Clean wool wt (g)	455.72	498.30	514.98	508.38	36.78
Length (cm)	8.77	9.72	9.17	9.00	0.62
Diameter (μm)	66.79	80.76	65.67	72.43	6.26

Mean fiber diameter, length, greasy and clean weight of the fleece as measured for the three breeds are presented in Table 28. Fleece yield (greasy and clean weight) from A×M sheep tended to be higher ($p<0.001$) than that of the Menz and Tukur sheep and no significant difference was noted between Menz and Tukur sheep. The increase in fleece weight was accompanied by an increase in body weight gain, which seems to be related more with breeds rather than feeding regimes. Gatenby *et al*. (1997) reported fleece weight to be more influenced by breed rather than treatment effects. In general, Ryder (1993) stated that lambs with heavier body weight produce correspondingly higher wool with the exception of Merino breeds. With two times shearing, Devendra and McLeroy (1982) reported a fleece yield of 2 kg for Tukur and 1.0 – 1.6 kg for Menz sheep. This yield seems quite high compared to the findings of this study (Table 28). The variance could be attributed to the difference in the number of cuts and the age disparity. In the current experiment, yearling sheep were used while the ages of the sheep in the earlier study were not specified. The mean fleece yields expressed by (Galal, 1983; Lemma *et al*., 1989; 1991) do concur with the findings of this study.

The fiber diameter and fleece length were found to be influenced by breed. The finest fiber came from Awassi×Menz crosses (61.79 μm) followed by Tukur sheep (63.87 μm) which were significantly different from Menz sheep (88.63 μm; $p<0.001$). None of the tested breeds qualify for a good quality wool taking the points given by Onions (1962), cited by Gatenby (1999). According to Onions (1962), wool should have a diameter of at least 40-50 μm to be classified as carpet wool implying the requirement for an integrated effort to improve the quality through varies breed improvement measures of which cross breeding is considered more potential. Lemma *et al*. (1998) obtained an increase in wool production as the level of exotic blood level increased from 50 to 75%. Fleece of A×M sheep was significantly longer ($p<0.0001$) than those of Menz and Tukur. The fiber length of Tukur sheep (9.29 cm) was also significantly ($p<0.0001$) longer than that of Menz sheep (6.70 cm). The report of Devendra and McLeroy (1982) with regard to fleece length, 10 cm for Tukur and 5-8 cm for Menz sheep is in close agreement with this finding (Table 28). The length of the fiber might further improved by adjusting the shearing dates, in line with market demands. But this deserves further investigation.

Table 28 Fleece characteristics of lambs fed with different levels of lotus hay.

Characteristics	Sheep breeds			SEM
	A×M	Menz	Tukur	
Greasy weight (g)	1,037.98^{a}	698.17^{b}	796.77^{b}	58.30
Clean wool wt (g)	573.00^{a}	425.11^{b}	484.92^{b}	30.61
Length (cm)	11.50^{a}	6.70^{c}	9.29^{b}	0.54
Diameter (μm)	61.79^{b}	88.63^{a}	63.87^{b}	5.57

^{abc} means in the same row with different superscripts are different ($p<0.05$).

Effect of the different levels of lotus hay on blood parameters is shown in Table 29. There were no treatment effects in hemoglobin (Hb) and plasma albumin (PA) ($p>0.05$), which is in agreement with that of Davis *et al.* (1999) who obtained no difference in goats. PCV and total protein (TP) revealed significant differences among lotus levels ($p<0.01$). The PCV was highest (32.38) in sheep supplemented with 400 g/h/d and was significantly different from that of 200 and the zero level ($p<0.01$); and no significant difference was noted among the 100 and 200 levels ($p>0.05$) and between the un-supplemented and 200 g/h/d groups (Table 29). Though statistically not different, the highest count of Hb (11.79) was obtained from the highest feeding treatment (400 g/h/d). The hemoglobin concentration of lambs for the different feeding treatment was found to be 11.29, 11.75, 11.47, and 11.79 for the 0, 100, 200, and 400 g/h/d, respectively. These values are within the range reported for Menz and A×M sheep supplemented with different levels of concentrates (Abunna, 1999). Thahar *et al.* (1983), Oyedipe *et a*l. (1984), and Taffesse (1987) observed that animals fed with good quality rations have higher values of RBC, PCV, and Hb concentration, which is in line with the current study.

Table 29 Influence of different levels of lotus on blood parameters of lambs.

Feeding level (g)	Blood parameters			
	PCV	Hb (g/dl)	PA (g/dl)	TP (g/dl)
0	30.34^{c}	11.29	4.34	7.48^{b}
100	31.74^{bc}	11.75	4.47	8.00^{a}
200	31.50^{c}	11.47	4.61	7.73^{ab}
400	32.38^{ab}	11.79	4.54	7.96^{a}
SEM	0.42	0.15	0.11	0.14

^{abc} means in the same column with different superscripts are different ($p < 0.05$).

The means PCV, Hb, PA, and TP of the three breeds are presented in Table 30. Difference in Hb and TP values were observed among the breeds ($p<0.01$ and $p<0.05$, respectively) while no difference was noted in PCV and PA values ($p>0.05$; Table 30). The Menz breed was significantly different in Hb and TP value from the other two breeds ($p<0.05$) (Table 30). No difference was noted in PCV and PA among the breeds. The PCV that is usually described in percentage is used to indicate the status of anemia; the more anemic, the lower the PCV count. Animals with PCV< 24% are considered to be anemic (Kelly, 1974). The PCV values of the three breeds (Table 30) were 31.35, 31.68, and 31.18 for A×M, Menz, and Tukur sheep, respectively; and are with in the range given for sheep (Schalam *et al.*, 1975; Jain, 1993) and are in line with the works done for the Menz sheep by Abunna (1999) and Tibbo *et al.* (2005). However, the PCV and Hb values in this study were a bit higher than reported by Tibbo *et al.* (2005) for Black Head Ogaden sheep of the lower altitudes of eastern Ethiopia. Significant difference ($p<0.05$) was noted among breeds in Hb and TP values (Table 30). Significantly higher value of TP was obtained from Menz. The Hb value, which is related with the O_2 carrying capacity, was in the range given by (Schalm *et al.*, 1975; Coles, 1986 and University of California, 2004). Furthermore, the values of 11.36 for Menz, 11.91 for A×M and 11.45 for Tukur indicate that the sheep are well adapted to the highlands. The Hb value of Menz and Tukur sheep is consistent with that of (Abunna, 1999 and Tibbo *et al.*, 2005) who evaluated the breeds in the different parts of the central highlands. A drop in Hb count indicates hemolytic disease of Babesioses, Anplasmosis and Leptospirosis (Schalm *et al*., 1975). Abunna (1999) did not find a significant difference between Menz and 50% A×M sheep breeds in Hb value. Tibbo *et al*. (2005) also found no difference between Menz and Tukur sheep, which is in a good agreement with the current findings (Table 30). An interaction was observed between breeds and Hb values.

Table 30 Breed effects on blood parameters of sheep fed with different levels of lotus hay

Breed	Blood measurements			
	PCV	Hb (g/dl)	PA (g/dl)	TP (g/dl)
A×M	31.35	11.91^{a}	4.53	7.70^{b}
Menz	31.68	11.36^{b}	4.46	8.00^{a}
Tukur	31.18	11.45^{a}	4.53	7.67^{b}
SE	0.37	0.13	0.97	0.95

^{abc} means in the same column with different superscripts are different ($p< 0.05$).

During the experimental period, two sheep were treated for respiratory and foot root cases. No mortality was observed during the experimental period in all of the breeds kept in the treatment.

EXPERIMENT IV The Effect of Mineral Supplementation on Live Weight Gain and Fiber Production of Three Sheep Breeds in the Central Highlands of Ethiopia.

The mean chemical and mineral content of the grazing pasture is given in Table 31. Accordingly, the pasture contained 0.85% Ca, 0.20% Mg; 0.28% P, 0.0087% Na and 1.71% K on DM basis (Table 31). The mean level of Ca and Mg in the pasture was sufficient (McDowell, 1997) as the values were above the borderline by 0.03% and 0.02%, respectively. The K level in the grazing pasture was found to be adequate and twice the requirement set for sheep by McDowell (1997). This is in agreement with Underwood (1981) who concluded that K deficiency is unlikely in tropical areas. The P level (0.28) was found to be on the borderline and calls for supplementation of P if the sheep are depend entirely on grazing. The Mg content may require attention as the level was near the borderline, while the Na level was found to be below the set requirement and needs absolute supplementation. Khalili *et al*. (1993) obtained a low level of Na in the central highlands of Ethiopia, which is consistent with the current findings. In fact, with the exception of Na and the marginal level of P, (Table 31) the macro mineral analysis of pastures indicates that the mineral contents of the pasture were above the range given by McDowell (1997) for sheep. The experiment was conducted during a season of peak growth of pastures with higher proportion of green leaves. This might be one of the most probable reasons why the pasture contained higher level of minerals. Orr (1929) as cited by Kabaija and Smith (1989) stated that mineral contents of forages are high at the stages when they are leafier and with less fibrous supporting tissues. However, chemical analysis shows how much of a given mineral nutrient is present, but does not necessarily indicate the bio-availability of the minerals (Peeler, 1972; McDowell, 1997).

Table 31 Chemical composition and mineral content of grazed pasture and soils.

Items	Requirement of sheep% [a]	Grazed pasture	Soil
Na %	0.09-0.18	0.0087	0.18
K%	0.50-0.80	1.71	0.61
Ca%	0.20-0.82	0.85	11.09
Mg%	0.12-0.18	0.20	1.54
P%	0.16-0.38	0.28	9.40
Dry matter %		91.04	-
Chemical composition, % of DM			
CP	-	15.69	-
Ash	-	9.99	-
NDF	-	63.46	-
ADF	-	36.75	-
Lignin	-	5.06	-
Cation exchange capacity		-	29.16
pH		-	4.77
Organic carbon		-	3.51

[a] Source: McDowell (1997)

According to McDowell (1997) if a mineral block contains 30-40% salt, the mixture is consumed on a free- choice basis, in the mean time providing other minerals. On the average, the lambs consumed 45.13 g (A×M), 52.96 g (Menz) and 47.96 g (Tukur) per week indicating that the Menz sheep licked more than the other breeds. However, the amount consumed by the breeds was found to be in line with the recommendation of the manufacturer. The manufacturer recommends a daily intake of 25 grams per 100 kg live weight, accordingly A×M, Menz and Tukur sheep consumed 6.45, 7.57, and 6.85 gram per day respectively.

The live weights and the corresponding carcass and non-carcass parameters are shown in Table 32 to 35. Body weight and carcass characteristics of the mineral supplemented and un-supplemented lambs are given in Table 32. Provision of mineral did not produce change in lamb live weight ($p>0.05$). This is in line with the findings of (Call *et al.*, 1978; Grace and Lee, 1992; Lemma, 1995) who did not find a difference with mineral supplementation. However, a trend in favor of the supplemented group was observed, as the live weight gain recorded was 8.91 kg against the 8.19 kg, for the un-supplemented group.

Table 32 Body weight and carcass characteristics of lambs supplemented and un-supplemented with minerals.

Characteristics	Un-supplemented	Supplemented	SEM
Initial weight (kg)	20.88	20.35	0.91
Final weight (kg)	28.65	28.91	0.84
Weight gain (kg)	8.19	8.91	0.53
Empty body weight (kg)	28.46	29.11	0.48
ADG (g)	68.26	74.27	4.39
Hot carcass weight (kg)	10.03	10.00	0.36
Dressing (%)	35.14	35.44	0.73
Viscera full (g)	5213.19	4547.92	276.45
Viscera empty (g)	563.33	591.67	13.43
Tail wt (g)	429.86	410.42	52.35

The breeds gained 9.10 kg (A×M) 7.70 kg (Menz) and 8.86 kg (Tukur) within the 120 days of the experiment (Table 33). The final weight gains recorded by the A×M sheep were significantly higher than those of the Menz and Tukur sheep ($p<0.05$). However, the variation between Menz and Tukur was insignificant ($p>0.05$). Numerically, the highest average daily gain (ADG) came from A×M (75.83) and Tukur (73.80 gram) per day, the lowest being from Menz sheep (64.17). With regard to the carcass, apart from the viscera full and empty all other parameters were found to be non-significant ($p>0.05$; Table 33).

Table 33 Body weight and carcass characteristics of three sheep breeds supplemented and un-supplemented with minerals.

Item	Breed			SEM
	A×M	Menz	Tukur	
Initial wt (kg)	25.13	18.25	18.47	1.11
Final weight (kg)	30.95^{a}	27.67^{b}	28.88^{b}	0.69
Weight gain (kg)	9.10	7.70	8.86	0.65
Empty body wt (kg)	33.88^{a}	25.53^{b}	26.95^{ab}	1.03
ADG (g)	75.83	64.17	73.80	5.47
Hot carcass wt (kg)	11.16^{a}	9.45^{b}	9.44^{b}	0.34
Dressing (%)	33.76	37.11	35.00	0.88
Viscera full (g)	6272.92^{a}	4162.50^{b}	4206.25^{b}	336.31
Viscera empty (g)	650.00^{a}	521.87^{b}	560.63^{ab}	16.34
Tail wt (g)	416.67	381.25	462.50	63.69

^{ab} means in the same row with different superscripts are different ($p<0.05$).

The result of mineral supplementation on non-carcass parameters is shown in Table 34. With the exception of spleen, all other non-carcass measurements were not influenced by the mineral supplementation ($p>0.05$). However, numerically higher values of heart, kidney, liver, feet, lung, and trachea came from the supplemented groups.

Table 34 Influence of minerals on non-carcass characteristics of lambs'.

Item	Un-supplemented	Supplemented	SEM
Head (g)	1862.43	1964.24	89.22
Feet (g)	548.91	578.17	13.59
Skin (g)	2308.84	2295.08	91.86
Heart (g)	113.43	130.32	9.18
Kidney (g)	57.25	64.84	3.90
Lung and trachea (g)	405.46	565.37	60.32
Spleen g)	49.65^{b}	68.68^{a}	4.17
Liver (g)	359.06	410.10	21.78

^{ab} means in the same row with different superscripts are different ($p<0.05$).

The non-carcass traits of the three breeds are shown in Table 35. Significantly higher values of feet and kidney were obtained from A×M sheep. As shown in the table, other non-carcass parameters were not influenced by breed. However, numerically higher value for the traits of skin and lung and trachea were obtained from A×M sheep.

Table 35 Non-carcass characteristics of the three sheep breeds supplemented and un-supplemented with minerals.

Item	Breed			SEM
	A×M	Menz	Tukur	
Head (g)	1979.17	1807.50	1900.00	176.21
Feet (g)	658.33^{a}	475.00^{b}	537.50^{a}	22.06
Skin (g)	2460.75	2232.50	2140.63	161.98
Heart (g)	143.75	103.13	112.50	13.54
Kidney (g)	70.83	50.00	59.00	5.26
Lung and trachea (g)	629.17	353.13	368.75	48.25
Spleen (g)	68.75	53.13	50.00	2.80
Liver (g)	462.50	315.63	334.38	24.08

^{ab} means in the same row with different superscripts are different ($p<0.05$).

PCV, Hb, TP and PA as affected by the treatments are presented in Table 36. None of the blood parameters deviates from the normal reference values given for sheep (Schalam *et al*., 1975; Jain, 1993; University of California, 2004). Under the conditions of this experiment, mineral supplementation did not bring about any impact on PCV, Hb, TP and PA. The absence of significant differences indicates that either the environment to which the sheep were exposed was not conducive to bring about differences between the supplemented and the un-supplemented groups or the sheep were well adapted to the environment.

Table 36 Influence of minerals on some blood variables.

Treatment	PCV	Hb (g/dl)	PA (g/dl)	TP (g/dl)
Un-supplemented	30.90	11.80	4.47	8.50
Supplemented	29.58	11.36	4.44	8.39
SEM	0.48	0.19	0.06	0.11

^{ab} means in the same column with different superscripts are different ($p<0.05$).

The means and standard errors of blood parameters (PCV, Hb, PA, and TP) of the three breeds are given in Table 37. Significant differences among breeds were obtained in Hb and TP ($p<0.05$). Higher and significantly different Hb (11.71) and TP (8.54) came from Menz sheep which was significantly higher than that of Tukur sheep (Table 37); while no difference was noted among the breeds in PCV and PA values ($p>0.05$). Breed by treatment interaction was observed in Hb.

Table 37 Influence of breeds on blood parameters.

Breed	PCV	Hb (g/dl)	PA (g/dl)	TP (g/dl)
A×M	31.25	11.69^{a}	4.56	8.50^{a}
Menz	30.28	11.71^{a}	4.46	8.54^{a}
Tukur	29.19	11.34^{b}	4.35	8.28^{b}
SEM	0.59	0.23	0.08	0.13

^{ab} means in the same column with different superscripts are different ($p<0.05$).

Mineral supplementation did not produce any influence (Table 38) on any of the fiber characteristics (p>0.05). This is in good agreement with that of (Niven and McMeniman, 1983; Grace and Lee, 1992) who found no differences in most of the wool characteristics with mineral supplementation. Numerically, the value obtained from the supplemented group was found to be high in greasy weight, though it fails to be significantly different.

Table 38 Effects of mineral supplementation on wool characteristics.

Treatment	Greasy (g)	Clean (g)	Length (cm)	Diameter (µm)
Supplemented	818.22	409.45	9.29	61.36
Un-supplemented	759.60	433.22	9.42	56.20
SEM	84.29	33.37	0.71	4.55

Fiber characteristic of lambs as influenced by breed is given in Table 39. None of the breeds differ from each other in any of the considered variables. The greasy yield obtained in this study for Menz sheep is comparable with that of (Galal, 1983; Lemma, *et al.*, 1993). Based on the classification given by Onions (1962) as cited by Gatenby (1999), wool could be rated into different classes taking its diameter. Accordingly, wool with a diameter of 18-24 µm is classified as Merino, 25-30 µm as crossbred, 30-45 µm as luster long wool and 40-50 µm as carpet wool. Hence, none of the breeds could be clustered in any of the classification given by Onions (1962) as they contained 55.76 µm (A×M), 63.59 µm (Menz) and 57.01 µm (Tukur). Fleece produced from these breeds does not comply with the commercial criteria to manufacture even carpets, though the fiber produced from the A×M is relatively better in its diameter.

Table 39 Measured wool parameters as influenced by breeds.

Breed	Greasy (g)	Clean (g)	Length (cm)	Diameter (µm)
A×M	971.80	501.35	10.13	55.76
Tukur	747.40	403.10	9.99	63.59
Menz	647.50	359.55	7.95	57.01
SEM	103.23	40.87	0.87	5.57

^{ab} means in the same column with different superscripts are different ($p<0.05$).

The response to minerals in the current experiment, which was carried out for 120 days, revealed insignificant in most of the measured variables. Thus, in order to draw a concrete conclusion, a mineral supplementation study that based on the deficient mineral/s should be executed based on prior animal tissue analysis.

EXPERIMENT V Effect of Natural Pasture Hay and Barley Straws Supplementation on Live Weight Gain and Fleece Production of Three Sheep Breeds in the Central Highlands of Ethiopia.

The chemical composition of the unimproved grazing pasture, hay and barely residue is presented in Table 40. The grazing pasture, hay and barley straws contained 40.83, 40.61, and 45.66 ADF and 63.84, 62.38, and 64.56 NDF, respectively. The DM of the same feeds was 91.04 (pasture), 91.69 (hay) and 91.47 (barley straws). CP of grazing pasture (9.47) was better than hay (5.98) and (2.96) barley straws (Table 40). Farmers of the central highlands, use crop wastes and hay as a supplement to over come feed shortages.

Table 40 Chemical composition of feeds used in the experiment (% DM basis).

Feed	DM%	Ash	CP	NDF	ADF	Hemicellulose
Natural pasture	91.04	9.99	9.47	63.84	40.83	23.01
Hay	91.69	9.35	5.98	62.38	40.61	21.77
Barley residue	91.47	10.17	2.96	64.56	45.66	18.90

Table 41 presents intake, live weight gains and carcass characteristics of the un-supplemented, barley straws and hay supplementation groups. The initial mean body weights of the lambs were 20.31 (barley), 20.88 (grazing) and 20.23 (hay). The result revealed that there was no variation among the treatment groups in any of the weight parameters apart the ADG. The ADG obtained from grazing only was found to be superior than barley supplemented group ($p<0.0001$). The mean daily DM intake was 219.33 and 71.26 g for hay and barley straws respectively, which was found to be significantly different ($p<0.05$) Table 41. However, there was no difference in final weight gain and weight gain among the treatments. The possible reason for this out come among the different treatment groups might be that the un-supplemented group has grazed enough pasture in day times to balance their total dry matter intake than the supplemented groups as pasture availability was not a limiting factor

Table 41 Live weight, ADG and feed consumption of lambs fed hay and barley straws

Traits	Grazing	Grazing+Barley	Grazing+Hay	SEM
Initial weight (kg)	20.88	20.31	20.23	0.90
Final weight (kg)	28.70	27.61	28.49	0.59
Weight gain (g)	8.19	7.15	8.04	0.58
Empty body weight (kg)	28.24	26.83	27.86	0.62
ADG (g)	68.26 ^{a}	59.62 ^{b}	66.98 ^{a}	4.87
Dressing %	35.01	35.58	35.12	0.66
Intake weight$^{0.75}$	-	10.76	10.89	0.31
Supplement total intake (g)	-	8211.03^{b}	25221.25 ^{a}	3039.86
Supplement daily intake (g)	-	71.26 ^{b}	219.33 ^{a}	26.44
Viscera full (g)	5202.06	3879.61	3918.33	282.11
Viscera empty (g)	550.10	513.62	572.53	19.55
Tail wt (g)	425.57	451.59	425.34	46.52

^{ab} means in the same row with different superscripts are different ($p<0.05$).

The average daily dry matter intake, body weight change and carcass parameters of the three sheep breeds are shown in Table 42. The average daily dry matter intake of the three lambs did not differ significantly among breeds ($p>0.05$). Values were 123.13 (A×M), 118.63 (Menz) and 194.14 (Tukur). However, intake per metabolic weight was found to be significantly different ($p<0.05$) among the breeds (Table 42). The low digestibility of hay and barley straws may have prevented the breeds to express their full genetic potential, which is in line with the suggestion of (Pearce, 1982; McDowell, 1988). The relatively lower intake of barley straws than hay might be due to the low passage rate of barley straws and rumen capacity, as rumen capacity determines the feed intake potential of an animal.

Table 42 Live weights, ADG and feed consumption of the three sheep breeds.

Traits	A×M	Menz	Tukur	SEM
Initial weight (kg)	24.96	18.23	18.23	0.90
Final weight (kg)	29.00	28.00	27.80	0.70
Weight gain (g)	8.14	7.72	7.52	0.58
Empty body weight (kg)	28.48	27.29	27.16	0.76
ADG (g)	67.85	64.34	62.67	4.87
Hot carcass weight (kg)	9.87	10.18	9.55	0.32
Dressing %	35.04	35.94	34.75	0.79
Intake weight$^{0.75}$	12.47^{a}	10.10^{b}	10.15^{b}	0.31
Supplemental intake (g)	14153.25	13653.75	22341.41	3722.05
Supplemental daily intake (g)	123.13	118.63	194.14	32.11
Viscera full (g)	5046.19^{a}	3937.32^{b}	4016.49^{b}	331.43
Viscera empty (g)	564.44	530.28	541.53	22.97
Tail (g)	372.34	457.79	472.37	54.65

^{ab} means in the same row with different superscripts are different ($p<0.05$).

Table 43 and 44 show the non-carcass components of different treatments and the three breeds respectively. As shown in the tables, neither the breed nor the treatments affected any of the parameters.

Table 43 Non-carcass characteristics as influenced by the feed types.

Traits	Grazing	Grazing+Barley	Grazing+Hay	SEM
Head (g)	1801.44	1817.29	1821.69	151.25
Feet (g)	542.30	575.58	565.46	19.61
Skin (g)	2233.02	1968.41	2271.49	99.43
Herat (g)	99.45	102.58	115.69	8.10
Kidney (g)	61.59	54.03	72.71	4.21
Lung and trachea (g)	408.73	373.58	337.69	15.59
Spleen (g)	48.81	64.72	50.21	6.73

Table 44 Non-carcass characteristics of the three sheep breeds.

Traits	A×M	Menz	Tukur	SEM
Head (g)	1882.49	1897.30	1660.63	177.68
Feet (g)	646.31	506.01	531.01	23.04
Skin (g)	1984.09	2295.45	2193.37	116.89
Heart (g)	112.63	102.32	102.76	9.48
Kidney (g)	81.66	52.30	54.38	4.94
Lung and trachea (g)	382.23	370.97	366.80	18.31
Spleen (g)	59.83	49.88	54.04	7.91
Liver (g)	388.53	330.32	324.07	18.66

The least square means for greasy and clean weight, length, and diameter of the treatments and breeds are presented in Table 45 and 45. A higher and significant difference in clean fleece yield was noted on lambs that were in the grazing group than those supplemented with hay or barley straws ($p<0.05$), and no difference was noted between the hay and barley straws supplemented group in any of the other variables. Though not significant the relatively finer diameter came from the supplemented group. This is in agreement with (Gallagher *et al*., 1966; Godfrey *et a*l., 1993) who obtained no difference among treatments in fiber production using clover or barley, respectively. Slen and Whiting (1952 a, b) have shown that wool growth is restricted when feed contained less than 8% protein, which is in line with this finding in which the protein levels of the supplemented feeds were 5.98 (hay) and 2.96 (barley straws) were below the set mark. The mean fiber diameter (Table 45) obtained from the lambs that were kept in barley straws (51.44), pasture (57.84) and hay (51.06 µm) was found to be insignificant ($p>0.05$), and was below the standard given by Onions (1962) as cited by (Gatenby, 1999). Wool fiber is affected by poor nutrition (Ryder, 1993), which reduces fiber diameter and processing performances. No significant difference was also observed in fiber length among treatments ($p>0.05$), this is in line with the findings of Smoliak and Slen (1972) who did not find difference in staple length from sheep that were under different intensities of grazing.

Table 45 Treatment effects on some fiber characteristics.

Treatment	Greasy (g)	Clean (g)	Length (cm)	Diameter (µm)
Grazing	818.22	409.45^{a}	9.29	57.84
Grazing+Barley	550.48	308.87^{b}	8.74	51.44
Grazing+Hay	694.08	374.26^{b}	8.56	51.06
SEM	86.37	51.57	0.77	4.34

^{ab} means in the same column with different superscript are different ($p<0.05$).

Overall, no significant difference was observed in any of the fleece parameters among the breeds. However, the fleece obtained from A×M sheep (840.30 g) was numerically higher than that of Menz (655.35) and Tukur (602.52 gram). The clean fleece yield obtained from A×M sheep was also numerically higher than Menz and Tukur sheep ($p<0.05$). The average clean fleece yield was found to be between 50-55% with in breed groups and was found to range between good and dirty clean fleece as described by Berger *et al.* (1989). Berger *et al.* (1989) stated that a good clean fleece to have a scoured fleece yield of 70 to 80%, and a dirty fleece to contain as low as 25 to 30%. Though not significantly different among the breeds ($p>0.05$), the longest and the finest fiber were also obtained from A×M sheep. None of the breeds qualify the standard given by Onions 1962 cited by Gatenby (1999) for wool diameter. Supplementation of barley straws and hay does not seem promising to increase productivity apart from its use to fill the gut and in general, cereal crop residues cannot maintain productivity if fed alone. Comparing Menz and Tukur sheep in terms of greasy weight, clean fleece and diameter though they performed similarly, the Menz showed a small advantage over the Tukur sheep (Table 46).

Table 46 Breed effects on some fiber characteristics.

Breed	Greasy (g)	Clean (g)	Length (cm)	Diameter (μm)
A×M	804.90	450.23	9.26	50.31
Menz	655.35	329.30	8.20	50.72
Tukur	602.52	313.04	9.13	59.32
SEM	86.37	34.35	0.77	4.34

^{ab} means in the same column with different superscripts are different ($p<0.05$).

The mean blood values of treatments and breeds are presented in Table 47 and 48. The PCV value 30.90, 30.81, and 30.38 for grazing, barley straws and hay, respectively were not significantly different ($p>0.05$) within treatments (Table 47) and holds true for Hb value ($p>0.05$). With regard to Hb numerically the highest concentration 13.61 was obtained from the barley straws supplemented group. Both PCV and Hb values were found to be in the range given by Schalam *et al*. (1975), Jain (1993) and University of California (2004).

Table 47 Influence of treatments on measured blood parameters.

Treatment	PCV	Hb (g/dl)	PA (g/dl)	TP (g/dl)
Grazing	30.90	11.79	4.47	8.52
Grazing+Barley	30.81	13.61	4.33	8.41
Grazing+Hay	30.38	11.45	4.40	8.27
SEM	0.40	1.14	0.05	0.10

Significant difference among breeds in PCV ($p<0.001$) and PA ($p<0.05$) were obtained (Table 48), while no difference was noted in Hb and TP values. The absence of significant differences in Hb and TP indicates that either the feed treatments were not adequate to bring about differences or the breeds are well adapted to the environment. However, Tibbo *et a*l. (2005) found a difference among the breeds of Menz, Wello and Tukur in erythrocytic series. The main cause for the difference might be variation of season. Only one season has been considered in the current study, while all seasons in the year were considered in their studies. The PCV value obtained for Menz was found to be in line with that of (Tibbo *et al.*, 2005). The values of PCV and Hb were within the normal ranges given by (Schalm *et al.*, 1975; Coles, 1986 and University of California, 2004).

Table 48 Influence of breeds on measured blood parameters.

Breed	PCV	Hb (g/dl)	PA (g/dl)	TP (g/dl)
A×M	32.09^{a}	11.72	4.56^{a}	8.49
Menz	30.79^{b}	11.78	4.33^{b}	8.52
Tukur	29.21^{b}	13.35	4.30^{b}	8.20
SEM	0.40	1.52	0.50	0.10

CONCLUSIONS AND RECOMMENDATIONS

The survey parts of this study revealed that any crop in excess of the household requirement is marketed and appropriated according the need of the family as crops cannot be stored indefinitely. A good amount of money from the sale of crop is invested in livestock as a means of saving and capital accumulation. Money required for daily or weekly expenditure is generated from the sale of animal products. The surveyed districts, though covering only 8% of the region's land mass, comprise 22% of the sheep, 25% of the horses, 16% of the mules, 3% of the asses, 11% of the goats and 9% of the cattle population of the region. In addition to grazing, straws of cereals and food legumes, browse species, hay and, to a lesser extent, by-products (flour and oil seed crushing plants) are used as animal feeds. Straws covers up to 40% of the dry season feed requirement of animals in the study area. The amount of crop residues produced in each district is a function of the area ploughed and the crop type and it lasts between 99 days in Gera Keya to 178 days in Tenta district. Sheep fattening is exercised in the districts and took 3 to 6 months on the average. Inadequate feed, various diseases, poor marketing systems coupled with insufficient extension system and credit services hindered livestock production in the area. Improvement of livestock production in this part of the country requires an integrated approach to overcome the problems associated with feed diseases and marketing.

Feeds that are used as supplement specifically straws and hay were found to be low in their nutritive value with a CP content of 3.33 and 7.56% and a digestibility of 34.07 and 42.50, respectively. Sodium, magnesium and phosphorus content of the feeds were below the recommended levels, while calcium and potassium contents were adequate for sheep. Indiscriminate supplementation of sodium is suggested since sodium is the most deficient minerals. Further research is recommended to evaluate and study the effect of deficient minerals on productivity of different livestock species.

From the feeding experiment it was observed that supplementation of *L. corniculatus* hay at a rate of 200 and 400 g/h/d during the dry season gave an advantage of 30% more live weight gain than the lower levels. Hence, farmers of the central highlands should be encouraged to use at least 200 g/h/d lotus hay as strategic dry season supplementation, as this could prevent losses of weight and productivity in the long dry season of the central highlands of Ethiopia. Further research is suggested to investigate the possibility of incorporating lotus hay into concentrate feeds to minimize cost of production.

Mineral supplementation when given on a free choice basis did not bring about an impact in weight gain and fleece production. It was concluded that supplementation of complete mineral blocks on a free choice basis in the wet season when the pasture is in active growth and is high in mineral content is not advisable for sheep of the central highlands of Ethiopia. Hence, it was suggested that the level of minerals in the host is primarily assessed by taking tissue samples so as to be certain that each animal gets its due share at the time of feeding/licking.

Supplementation of barley straws and natural pasture hay during the wet season did not improve body weight and fleece characteristics of sheep of the central highlands of Ethiopia. It is suggested that hay and crop residues be used only as a maintenance ration since both are low in CP and minerals. Improvement of the nutritive value of crop residues and native pasture hay by mixing or incorporating them with locally available feed resources requires further investigation.

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Appendix 1 Metrological data of the surveyed region of Amhara Regional State.

District	Item	Month											
		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Debark	RF (mm)	0.64	2.54	16.33	35.79	77.11	156.61	268.89	284.91	123.60	61.79	17.10	4.82
	Max °C	20.10	21.40	21.61	22.87	21.27	18.41	16.45	16.39	18.17	19.43	19.80	20.2
	Min °C	6.65	8.22	8.96	9.57	10.33	10.43	9.53	9.34	8.66	7.63	6.71	6.22
Gera Keya	RF (mm)	18.5	11.50	61.42	45.56	33.27	38.77	335.69	253.00	53.82	21.71	6.68	6.03
	Max °C	18.5	19.60	18.88	18.89	19.20	19.75	16.89	16.75	17.06	14.83	16.80	18.0
	Min °C	5.92	7.16	7.80	8.34	8.81	8.23	8.07	8.06	7.71	6.51	4.96	5.41
Were Ilu	RF (mm)	20.1	16.4	51.58	33.19	22.98	57.07	375.03	267.86	45.19	6.64	7.18	8.02
	Max °C	21.7	22.7	22.54	22.73	23.19	23.74	20.18	19.63	20.62	20.67	18.60	21.0
	Min °C	6.29	7.06	8.29	9.39	9.61	8.64	9.50	9.21	8.79	8.60	6.44	5.87
Wegera	RF (mm)	1.02	4.15	15.45	31.67	65.92	133.48	324.16	255.73	58.04	33.55	20.55	4.56
	Max °C	18.60	19.40	20.64	20.67	20.55	17.94	15.85	16.14	17.87	18.02	17.00	18.20
	Min °C	5.97	7.57	8.32	8.85	9.32	9.18	8.75	8.57	8.31	7.80	6.25	5.81
Lay Gayint	RF (mm)	14.60	15.10	62.70	77.96	61.16	62.32	301.34	267.22	28.66	49.14	30.20	13.2
	Max °C	18.20	19.18	20.01	20.02	19.89	20.56	17.08	16.42	16.25	17.37	16.35	16.33
	Min °C	6.32	7.28	8.17	8.74	8.51	8.56	8.34	7.82	7.73	6.60	5.42	5.14
Lalo Midir	RF (mm)	10.70	6.0	44.50	30.72	31.20	27.58	383.02	331.82	75.63	25.70	5.38	2.25
	Max °C	15.1	na	na	na	na	14.9	12.4	11.80	14.80	14.60	14.60	15.10
	Min °C	5.96	6.68	8.12	8.46	9.10	7.8	8.2	8.38	8.32	7.27	5.55	5.87
Farta	RF (mm)	5.35	2.56	32.79	45.65	108.30	175.69	419.4	401.12	202.35	99.10	23.70	19.0
	Max °C	23.10	24.10	24.30	23.98	21.68	18.38	18.56	20.09	20.01	20.94	21.50	22.10

Appendix 2 Long term mean monthly maximum and minimum temperatures and rainfall of Debre Berhan Research Center.

Month	Rain fall (mm)		Maximum temp.		Minimum temp.	
January	15.6	(9.81)	20.30	(19.49)	5.33	(4.37)
February	36.3	(22.21)	21.36	(20.30)	6.85	(5.74)
March	60.2	(52.39)	21.21	(20.56)	7.93	(6.74)
April	85.7	(9.50)	20.77	(0.49)	9.47	(7.60)
May	3.8	(38.91)	22.49	(21.47)	7.02	(7.14)
June	99.5	(45.81)	22.49	(21.90)	7.80	(7.13)
July	334.1	(289.01)	18.05	(18.55)	9.68	(8.74)
August	288.7	(272.57)	18.28	(18.14)	9.56	(8.72)
September	74.2	(84.39)	18.99	(18.67)	8.11	(7.12)
October	0	(19.70)	19.38	(18.47)	2.99	(3.65)
November	0	(5.19)	19.13	(18.74)	2.74	(1.84)
December	7.4	(3.71)	19.43	(19.03)	1.64	(0.86)

Figures in parenthesis indicate means of 18 years.

Appendix 3 ANOVA tables for sheep supplementation experiments

3.1 ANOVA table for weight gain

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	112.87390625	37.62463542	32.25	0.0001
B = Breed	2	79.17281250	39.58640625	30.65	0.0001
AxB	6	11.0859370	1.84765625	1.51	0.2004
Error	36	44.19062500	1.22751736		
Corrected total	47	247.32328125			
R-square = 0.821324			CV = 27.98254		

3.2 ANOVA table for average daily gain

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	7841.96912817	2748.20324702	30.66	0.0001
B = Breed	2	5496.40649404	2613.98970939	32.24	0.0001
AxB	6	769.58085896	128.26347649	1.50	0.2046
Error	36	3068.87204350	85.24644565		
Corrected total	47	17176.82852467			
R-square = 0.821337			CV = 27.98626		

3.3 ANOVA table for hot carcass weight

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	15.82046250	7.10141875	3.33	0.0301
B = Breed	2	21.30425625	7.91023125	3.71	0.0342
AxB	6	1.75338750	0.29223125	0.14	0.9904
Error	36	76.7070750	2.13075208		
Corrected total	47	115.58518125			
R-square = 0.336359			CV = 15.37244		

3.4 ANOVA table for dressing percentage

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	39.96990833	13.32330278	1.53	0.2246
B = Breed	2	170.83932917	85.41966458	9.78	0.0004
AxB	6	49.17315417	8.19552569	0.94	0.4801
Error	36	314.51320000	8.7364778		
Corrected total	47	574.495591617			
R-square = 0.452540			CV = 6.947426		

3.5 ANOVA table for viscera full

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	0.64204465	0.21401488	0.21	0.8916
B = Breed	2	17.27856417	8.63928209	8.31	0.0011
AxB	6	5.30289195	0.88381532	0.85	0.5405
Error	34	35.33243333	1.03918922		
Corrected total	45	57.43006087			

R-square = 0.384775 CV = 24.55372

3.6 ANOVA table for viscera empty

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	18300.15765766	6100.05255255	1.13	0.3519
B = Breed	2	12714.85042735	6357.42521368	1.18	0.3212
AxB	6	26788.5578344	4464.75963907	0.83	0.5585
Error	33	178640.41666667	5407.89141414		
Corrected total	44	239191.1111111			

R-square =0.253900 CV = 13.75692

3.7 ANOVA table for head

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	0.57630625	0.19210208	2.21	0.1034
B = Breed	2	0.04567917	0.02283958	0.26	0.7701
AxB	6	0.22983750	0.03830625	0.44	0.8462
Error	36	3.12487500	0.08680208		
Corrected total	47	3.97669792			

R-square = 0.214204 CV = 16.64727

3.8 ANOVA table for feet

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	15380.250000	5126.7500000	0.77	0.5205
B = Breed	2	30640.1666667	15320.0833333	2.29	0.1159
AxB	6	17750.5000000	2958.41666667	0.44	0.8456
Error	36	240873.000000	6690.9166667		
Corrected total	47	304643.91666667			

R-square = 0.209329 CV = 15.79239

3.9 ANOVA table for skin

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	0.47787292	0.15929097	1.07	0.3729
B = Breed	2	0.16336250	0.08168125	0.55	0.5817
AxB	6	0.41572083	0.6928681	0.47	0.8284
Error	36	5.34647500	0.14851319		
Corrected total	47	6.40343125			
R-square = 0.165061			CV = 16.37712		

3.10 ANOVA table for heart

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	11506.250000	3835.41666667	1.32	0.2814
B = Breed	2	7350.0000000	3675.00000000	1.27	0.2933
AxB	6	14550.0000000	2425.0000000	0.84	0.5492
Error	36	104225.000000	2895.1388889		
Corrected total	47	137631.2500000			
R-square = 0.242723			CV = 47.56375		

3.11 ANOVA table for kidney

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	256.2500000	85.41666667	0.29	0.8318
B = Breed	2	579.16666667	289.33333333	0.99	0.3830
AxB	6	2187.500000	364.58333333	1.24	0.3088
Error	36	10575.000000	293.75000000		
Corrected total	47	13597.916666667			
R-square = 0.222307			CV = 27.88741		

3.12 ANOVA table for lung and trachea

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	29675.00000	9891.66666667	1.09	0.3654
B = Breed	2	31587.00000	15793.7500000	1.74	0.1897
AxB	6	24412.500000	4068.7500000	0.45	0.8410
Error	36	326450.00000	9068.055555556		
Corrected total	47	412125.00000			
R-square = 0.2078886			CV = 23.73242		

3.13 ANOVA table for 5pleen

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	408.33333333	136.1111111	0.38	0.7702
B = Breed	2	129.1666666667	64.58333333	0.18	0.8370
AxB	6	1054.1666666667	175.69444444	0.49	0.8140
Error	36	13000.00000000	361.1111111		
Corrected total	47	14591.6666666667			

R-square = 0.109081 CV = 36.48561

3.14 ANOVA table for liver

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	23291.66666667	7763.88888889	1.37	0.2673
B = Breed	2	2516.66666667	1258.33333333	0.22	0.8019
AxB	6	18683.33333333	3113.888888889	0.55	0.7668
Error	36	203900.00000000	5663.888888889		
Corrected total	47	248391.666666667			

R-square = 0.179119 CV = 25.12116

3.15 ANOVA table for greasy

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	90537.20109910	30179.06703303	0.55	0.6485
B = Breed	2	882829.84375494	441414.92187747	8.12	0.0014
AxB	6	134387.48632576	22397.91438763	0.41	0.8658
Error	33	1794591.31583334	54381.55502525		
Corrected total	44	2911684.34311112			

R-square = 0.383659 CV = 27.55912

3.16 ANOVA table for clean fleece weight

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	23027.59645419	7675.86548473	0.51	0.6769
B = Breed	2	158442.13104302	79221.06552151	5.28	0.0102
AxB	6	31458.0628064	5243.01046774	0.35	0.9050
Error	33	494850.31157501	14995.46398712		
Corrected total	44	714890.06756446			

R-square = 0.307795 CV = 24.69801

3.17 ANOVA table for length

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	5.864883333	1.9549611	0.42	0.7404
B = Breed	2	184.77371667	92.38685833	19.80	0.0001
AxB	6	38.71421667	6.45236944	1.38	0.2480
Error	36	167.96755000	4.6657528		
Corrected total	47	397.32036667			
R-square = 0.577249			CV = 23.57048		

3.18 ANOVA table for diameter

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	1681.39256197	560.46418732	1.22	0.3160
B = Breed	2	7058.70008136	3529.35004068	7.70	0.0017
AxB	6	1354.45449028	225.74241505	0.49	0.8096
Error	35	16046.01756667	458.45764476		
Corrected total	46	25895.72036596			
R-square = 0.380360			CV = 29.79595		

3.19 ANOVA table for PCV

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	137.3095741	45.7698580	4.15	0.0069
B = Breed	2	10.6554618	5.327309	0.48	0.6176
AxB	6	79.0927583	13.1821264	1.19	0.3099
Error	228	2515.656767	11.033582		
Corrected total	239	2741.395833			
R-square = 0.082345			CV = 10.58001		

3.20 ANOVA table for Hb

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	10.30686727	3.43562242	2.64	0.0503
B = Breed	2	13.70050688	6.85025344	5.26	0.0058
AxB	6	24.86933857	4.14489976	3.18	0.0051
Error	228	296.7441155	1.3015093		
Corrected total	239				
R-square = 0.139273			CV = 9.859806		

3.21 ANOVA table for PA

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	1.112283049	0.37427683	0.50	0.6857
B = Breed	2	0.28025994	0.14012997	0.19	0.8308
AxB	6	6.33715586	0.55619264	0.74	0.6208
Error	228	172.2085634	0.7553007		
Corrected total	239	177.0101983			
R-square = 0.027126			CV = 19.26331		

3.22 ANOVA table for TP

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	3	10.17213229	3.39071076	4.69	0.0034
B = Breed	2	5.546476671	2.73238336	3.78	0.0242
AxB	6	6.18267669	1.0304461	1.43	0.2055
Error	228	164.7727420	0.7226875		
Corrected total	239	186.2265296			
R-square = 0.115203			CV = 10.91535		

4.1 ANOVA table for empty body weight

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	0.4266666667	0.42666666667	0.05	0.8249
B = Breed	2	319.22333333	159.611666667	18.86	0.0001
AxB	2	2.9033333333	1.4516666667	0.17	0.8437
Error	18	152.32000000	8.4622222222		
Corrected total	23	474.87333333			
R-square = 0.679241			CV = 10.10651		

4.2 ANOVA table for weight gain

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	3.11760417	3.11760417	0.90	0.3545
B = Breed	2	8.95020833	4.47510417	1.30	0.2978
AxB	2	4.57895833	2.28947917	0.66	0.5273
Error	18	62.12562500	3.45142361		
Corrected total	23	78.77239583			
R-square = 0.211327			CV = 21.72337		

4.3 ANOVA table for average daily gain

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	216.50028945	216.50028945	0.90	0.3545
B = Breed	2	621.54224528	310.77112264	1.30	0.2978
AxB	2	317.98321761	158.99160881	0.66	0.5273
Error	18	4314.27951379	239.68219521		
Corrected total	23	5470.30526614			
R-square = 0.211327			CV = 21.72337		

4.4 ANOVA table for hot carcass

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	0.00742424	0.00742424	0.01	0.9400
B = Breed	2	10.83971026	5.41985513	4.27	0.0340
AxB	2	1.38334103	0.69167051	0.55	0.5908
Error	15	19.02746667	1.26849778		
Corrected total	20	32.60129524			
R-square = 0.416359			CV = 11.41055		

4.5 ANOVA table for dressing percentage

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	0.45169091	0.45169091	0.09	0.7725
B = Breed	2	37.17123077	18.58561538	3.57	0.0541
AxB	2	22.28022308	11.14011154	2.14	0.1525
Error	15	78.17350000	5.21156667		
Corrected total	20	137.15722857			
R-square = 0.430045			CV = 6.420329		

4.6 ANOVA table for viscera full

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	2172736.7424242	2172736.74242425	2.89	0.1098
B = Breed	2	16113525.641025	8056762.82051283	10.72	0.0013
AxB	2	3856410.2564102	1928205.12820513	2.56	0.1102
Error	15	11278541.666666	751902.77777778		
Corrected total	20	34667678.571428			
R-square = 0.674667			CV = 18.57647		

4.7 ANOVA table for viscera empty

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	3940.90909091	3940.90909091	13.99	0.0004
B = Breed	2	47012.20238095	23506.10119048	13.24	0.0005
AxB	2	981.2500000000	490.625000000	0.28	0.7624
Error	15	26637.50000000	1775.8333333		
Corrected total	20	77880.95238095			

R-square = 0.657972 CV = 7.445969

4.8 ANOVA table for tail weight

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	1856.06060606	1856.06060606	0.07	0.7966
B = Breed	2	26506.41025641	13253.20512821	0.49	0.6212
AxB	2	36939.10256410	18469.55128205	0.68	0.5192
Error	15	404479.16666667	26965.27777778		
Corrected total	20	468095.23809524			

R-square = 0.135904 CV = 38.74643

4.9 ANOVA table for head

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	1751.515152	1751.51515152	0.01	0.9278
B = Breed	2	92302.56410256	46151.28205128	0.22	0.8023
AxB	2	96225.64102564	48112.82051282	0.23	0.7949
Error	15	3096366.66666667	206424.4444444		
Corrected total	20	3270130.95238095			

R-square = 0.53137 CV = 24.17925

4.10 ANOVA table for feet

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	606.06060606	69994.40192308	0.40	0.5360
B = Breed	2	101025.64102564	159714.36726191	0.92	0.4215
AxB	2	6650.64102564	34524.21153846	0.20	0.8225
Error	15	48541.66666667	174429.4833333		
Corrected total	20	155416.66666667			

R-square = 0.687668 CV = 10.50218

4.11 ANOVA table for skin

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	69994.40192308	69994.40192308	0.40	0.5360
B = Breed	2	319428.73452381	159714.36726191	0.92	0.4215
AxB	2	69048.42307692	34524.21153846	0.20	0.8225
Error	15	2616442.25000001	174429.4833333		
Corrected total	20	3074913.80952381			
R-square = 0.149101			CV = 18.54759		

4.12 ANOVA table for heart

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	532.67045455	532.67045455	0.44	0.5186
B = Breed	2	5120.19230769	2560.09615385	2.10	0.1569
AxB	2	1562.50000000	781.25000000	0.64	0.5406
Error	15	18281.25000000	1218.7500000		
Corrected total	20	24345.23809524			
R-square = 0.249083			CV = 30.23186		

4.13 ANOVA table for kidney

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	116.00378788	116.00378788	0.63	0.4396
B = Breed	2	1314.00378788	657.05128205	3.57	0.0539
AxB	2	64.10256410	32.05128205	0.17	0.8418
Error	15	2760.416666667	184.027777778		
Corrected total	20	4166.66666667			
R-square = 0.337500			CV = 23.25546		

4.14 ANOVA table for lung and trachea

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	27104.64015152	27104.64015152	1.75	0.2055
B = Breed	2	266626.60256410	133313.30128205	8.61	0.0032
AxB	2	151626.60256410	75813.30128205	4.90	0.0230
Error	15	232135.41666667	15475.69444444		
Corrected total	20	599166.6666667			
R-square = 0.612570			CV = 29.85632		

4.15 ANOVA table for spleen

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	1044.03409091	1044.03409091	20.05	0.0004
B = Breed	2	1129.80769231	564.90384615	10.85	0.0012
AxB	2	1129.80769231	564.90384615	10.85	0.0012
Error	15	781.250000000	52.08333333		
Corrected total	20	3273.80952381			
R-square = 0.761364			CV = 13.17865		

4.16 ANOVA table for greasy weight

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	20615.48166667	20615.4816667	0.24	0.6288
B = Breed	2	441462.0933333	220731.04666667	2.59	0.1027
AxB	2	244185.9433333	122092.9716667	1.43	0.2647
Error	18	1534569.3800000	85253.8544444		
Corrected total	23	2240832.8983333			
R-square = 0.307850			CV = 27.43361		

4.17 ANOVA table for clean fleece weight

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	3391.028266667	3391.0282667	0.25	0.6205
B = Breed	2	84409.54090000	42204.77045000	3.16	0.667
AxB	2	19160.840033333	9580.42001667	0.72	0.5016
Error	18	240485.1165000	13360.28403611		
Corrected total	23	347446.52185000			
R-square = 0.307850			CV = 27.43361		

4.18 ANOVA table for fiber length

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	0.10773600	0.10773600	0.02	0.8955
B = Breed	2	23.68256533	11.84128267	1.95	0.1714
AxB	2	12.05590000	6.02795000	0.99	0.3902
Error	18	109.37354200	6.07630789		
Corrected total	23	145.219743333			
R-square = 0.246841			CV = 26.34456		

4.19 ANOVA table for diameter

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	151.57584799	151.57584799	0364	0.4331
B = Breed	2	272.07107160	136.03553580	0.58	0.5714
AxB	2	780.10564270	390.05282135	1.66	0.2197
Error	17	3997.29696359	235.13511551		
Corrected total	22	5221.91428585			
R-square = 0.234515			CV = 26.10434		

4.20 ANOVA table for PCV

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	41.343750000	41.34375000	3.76	0.5556
B = Breed	2	68.14583333	34.07291667	3.10	0.0499
AxB	2	20.81250000	10.406250000	0.95	0.3918
Error	90	989.1875000	10.99097		
Corrected total	95	1119.489583			
R-square = 0.116394			CV = 10.96332		

4.21 ANOVA table for hb

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	4.770211667	4.77041667	2.84	0.0954
B = Breed	2	2.857500000	1.42875000	0.85	0.4306
AxB	2	0.758333333	0.03791667	0.02	0.9777
Error	90	151.1825000	1.6798056		
Corrected total	95	158.88625000			
R-square = 0.048486			CV = 11.19113		

4.22 ANOVA table for PA

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	0.02220417	0.02220417	0.12	0.7313
B = Breed	2	0.71407708	0.35703854	1.91	0.1543
AxB	2	0.27241458	0.13620729	0.73	0.4857
Error	90	16.83783750	0.18708708		
Corrected total	95	17.84653333			
R-square = 0.056521			CV = 9.705362		

4.23 ANOVA table for TP

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	1	0.29537109	0.29537109	0.54	0.4657
B = Breed	2	1.24887344	0.62443672	1.13	0.3260
AxB	2	1.81710469	0.90855234	1.65	0.1976
Error	90	49.52043594	0.55022767		
Corrected total	95	52.88178516			
R-square = 0.063563			CV = 8.785038		

5.1 ANOVA table for supplemental feed intake

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	122614.0844	61307.0422	8.68	0.0079
B = Breed	2	7971.4978	3985.7489	0.56	0.5876
AxB	4	21301.0622	5325.2656	0.75	0.5800
Error	9	63555.6600	7061.7400		
Corrected total	17	215442.3044			
R-square = 0.704999		CV = 83.08332			

5.2 ANOVA table for supplemental feed daily intake

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	321.3236408	160.6618204	339.45	<0.0001
B = Breed	2	0.2153498	0.1076749	0.23	0.8010
AxB	4	0.3863309	0.0965827	0.20	0.9298
Error	9	4.2596570	0.4732952		
Corrected total	17	326.1849784			
R-square = 0.986941			CV = 22.01095		

5.3 ANOVA table for weight gain

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	2413.402500	1206.701250	2.42	0.1439
B = Breed	2	9.300833	4.650417	0.01	0.9907
AxB	4	3453.751667	863.437917	1.73	0.2261
Error	9	4481.03625	497.89292		
Corrected total	17	10357.4917			
R-square = 0.567363		CV = 42.97258			

5.4 ANOVA table for dressing percentage

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	19787.44444	9893.722222	1.45	0.2847
B = Breed	2	37915.11111	18957.55556	2.78	0.1150
AxB	4	32803.888889	8200.97222	1.20	0.3743
Error	9	61449.50000	6826.72222		
Corrected total	17	151946.94444			
R-square = 0.595645			CV = 140. 726		

5.5 ANOVA table for head

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	990902.778	495451.389	1.54	0.2665
B = Breed	2	943819.444	471909.722	1.46	0.2665
AxB	4	1339722.222	334930.556	1.04	0.4385
Error	9	2900312.500	322256.9444		
Corrected total	17	617456.944			
R-square = 0.530295			CV = 91.84883		

5.6 ANOVA table for heart

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	57569.4444	28784.2222	2.90	0.1067
B = Breed	2	2986.1111	1493.05556	0.15	0.8625
AxB	4	19097.2222	4774.30556	0.48	0.7498
Error	9	5625.000	645.000		
Corrected total	17	235000.00			
R-square = 0.976064			CV = 18.75		

5.7 ANOVA table for lung and trachea

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	6358415.19	3179207.60	1.24	0.3340
B = Breed	2	5293111.19	2646555.60	1.03	0.3943
AxB	4	10574864.22	2643716	1.03	0.4414
Error	9	23041480.63	2560164.51		
Corrected total	17	45267871.24			
R-square = 0.490997			CV = 42.51926		

5.8 ANOVA table for greasy weight

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	407532.65158046	203766.32579023	2.366	0.1144
B = Breed	2	247378.57494253	123689.28747126	1.43	0.2570
AxB	4	310152.17884409	77538.04471102	0.90	0.4795
Error	26	2245591.0750000	86368.88750000		
Corrected total	34	3247846.32971429			
R-square = 0.308591			CV = 42.51926		

5.9 ANOVA table for clean fleece weight

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	58641.46790414	29320.73395207	2.22	0.1296
B = Breed	2	117654.78582688	58827.39291344	4.45	0.0222
AxB	4	22632.00181486	5658.0045372	0.43	0.7867
Error	25	330227.48046666	13209.09921867		
Corrected total	33	538681.88109411			
R-square = 0.386971		CV = 31.84547			

5.10 ANOVA table for fiber length

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	3.36006791	1.6800395	0.25	0.7777
B = Breed	2	7.70334861	3.85167431	.58	0.5660
AxB	4	10.87962993	2.71990748	0.41	0.7988
Error	25	165.35929136	6.61437165		
Corrected total	33	188.103999803			
R-square = 0.120916			CV = 28.96346		

5.11 ANOVA table for fiber diameter

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	316.74303338	158.37151669	0.78	0.4716
B = Breed	2	558.542865333	279.27143266	1.37	0.2738
AxB	4	955.28810833	238.82202708	1.17	0.3490
Error	24	4900.35784950	204.18157706		
Corrected total	32	6891.73578294			
R-square = 0.288952			CV = 26.57160		

5.12 ANOVA table for PCV

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	9.8836176	4.9418088	0.49	0.6157
B = Breed	2	192.2534687	96.1267343	9.47	0.0001
AxB	4	27.0577301	6.764325	0.67	0.6165
Error	131	1329.866071	10.151649		
Corrected total	135	1553.221429			
R-square = 14.3801			CV = 10.36633		

5.13 ANOVA table for Hb

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	129.003163	64.5015681	1.04	0.3558
B = Breed	2	81.6230024	40.8115012	0.66	0.5191
AxB	4	204.0544856	51.0136214	0.82	0.5123
Error	134	8300.371833	61.943073		
Corrected total	142	8718.294266			
R-square = 0.047036			CV = 64.04154		

5.14 ANOVA table for PA

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	0.49579194	0.24789597	1.05	0.3537
B = Breed	2	1.76138688	0.88069344	3.72	0.0268
AxB	4	1.18442773	0.29610693	1.25	0.2926
Error	137	30.04603214	0.23658293		
Corrected total	135	33.44961176			
R-square = 0.101752			CV = 11.04490		

5.15 ANOVA table for TP

Source	DF	SS	MS	F Value	Pr>F
A = Treatment	2	1.50400394	1.04667036	1.86	0.1600
B = Breed	2	2.09334073	0.75200197	1.34	0.2666
AxB	4	1.60610699	0.40152675	0.71	0.5842
Error	122	68.64741530	0.56268373		
Corrected total	130	74.39256489			
R-square = 0.0772227			CV = 8.927190		

Appendix 4 Survey Questionnaire

Date__________ Zone ____________ District_________ Village ________

1. Type of feed used as a supplement a) hay b) spent grain c) concentrates d) crop residue e) by products of flour mills d) browse species e)others specify

2. Time of feeding supplements a) early in the morning b) during enclosure time

3. Animals preferred for supplementation a) oxen b) sheep c) dairy cows d) goats e) pack animals

4 Amount offered (if possible weigh if not guess)

5. Period preferred for fattening a) Religious holidays b) New Year c) at any time of the year

6. Duration of fattening a) less than 3 months b) three to six months c) more than 6 months

7. Treatment of browse species a) chopping b) welting c) boiling d) other specify

8. Experience of mineral (salt block) supplement a) yes b) no

9. Period preferred for mineral (salt block) supplementation

10 Cost of the mineral (salt block)

11. Animals owned a) poultry b) sheep c) goats d) dairy cows e) ox f) pack animals g) others

12.. Objective of sheep rearing a) sale b) home consumption c) wool production d) manure e) others specify

13. When do sale sheep a) period of food scarcity b) at times of holydays c) to pay government debt d) others specify

14 Source of family income a) crop b) live animal sale c) animal products d) any other

15. Is there a wool market in near by a) yes b) no

16. Average distance to the market

17. Number of shearing per annum

18 Do you select sheep for wool purpose?

19. Have you ever used improved rams?

16. If yes advantage obtained

20. Major cause of sheep mortality a) disease b) predators c) accidents d) starvation e) others specify

21. What do you do with the wool a) sale b) weaving c) pillow stuffing d) others specify

22. When do you sale wool a) just after shearing b) on latter days

23. Do you process fiber before sailing a) color sorting b) scouring c) spinning d) others specify

24. Extension service rendered in the vicinity a) sheep husbandry b) sheep fattening c) fiber production d) fiber processing

25 Is there credit service in your area with regard to sheep?

26 Source of credit a) governmental b) non governmental

27 Availability of water a) adequate b) not adequate

28. Source of water

29 Suggested pasture management systems to improve productivity