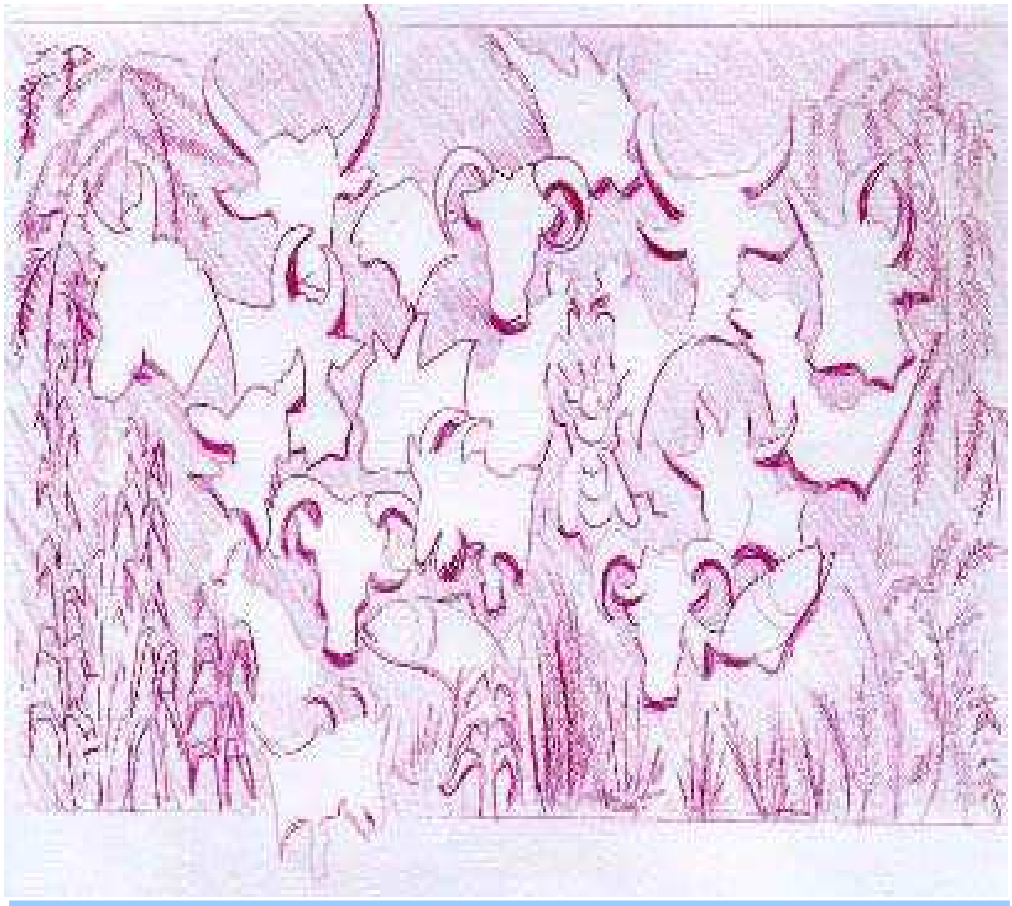
Ethiopian Journal of Animal Production

Volume: 6 Number: 1 2006 ISSN: 1607-3835



Official Journal of the Ethiopian Society of Animal Production (ESAP)

Ethiopian Journal of Animal Production

An Official Journal of the Ethiopian Society of Animal Production (ESAP)

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

EJAP is published by the Ethiopian Society of Animal Production (ESAP)

This issue is sponsored by the Ethiopian Science and Technology Commission

EJAP
ISSN: 1607-3835
Volume 6, Number 1
2006

Cover page by Wossene Abay

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The Occurrence of Chalk Brood (*Ascosphaera apis)*: A Honeybee (*A. mellifera L.*) Disease in West Shoa, Ethiopia

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Abstract

Though the moral principles and techniques of detection and treatment of honeybee diseases, pests and predators have been well documented, their distributions are not adequately surveyed throughout the world. Chalk brood is honeybee larvae disease caused by fungus called *Ascosphaera apis*. This disease has not been reported to exist in Ethiopia. A random sample survey was made around Holetta and at Gedo demonstration site based on the clue for disease symptoms at Holetta bee research apiary & complaints from farmer beekeepers. This was done following the brood season (October-January 2001) to confirm the existences of chalk brood disease in Ethiopia. A total of 13 apiaries surveyed and 276 bee colonies inspected. Of the total inspected colonies, 48 bee colonies were sampled with the collections of 240 dead & dry bee larvae (black mummies) (5 per colony) for laboratory diagnosis. From the 13 inspected apiaries, 8 (about 61%) of them were positive to the chalk brood (*A. apis*) with 0-100% prevalence & 17.4% of overall average colonies infections. This is the first report of *A. apis* in Ethiopia. Therefore, attention should be given to assess its ecology, magnitude of the problem and find control options under the prevailing local condition.

Keywords: *Ascosphaera apis,* Chalk brood, *Apis mellifera*, mummified, Ethiopia

Introduction

Principles and techniques of detection and treatment of honeybee diseases and parasites have been well docmented (Morse, 1978). However, their magnitude of distribution and economic threshold is not adequately surveyed and determined for all honeybee diseases and parasites in all over the world.

Chalk brood is an infectious disease of honeybee larvae caused by a fungus *Ascosphaera apis,* which causes death and mummification of sealed brood of honeybee with consequent weakness of the colony (Root, 1990). It is a widespread honeybee disease in Europe and North America and its causative

organism *Ascosphaera apis* has been determined in U.S. in 1968 (Hitchock and Christensen, 1972) and in Canada in 1971 (Gochnauer *et al*., 1972). In Africa the only report of chalk brood so far was from Tunisia (Heath, 1985). The disease is spread by robbing, drifting bees and by the normal practice of beekeeping (Peter, 1998). The *Ascosphaera apis* sticky spores are commonly present on adult bees and all surfaces within occupied hives, suggesting its speedy distribution from place to place & from apiaries to apiary. The disease develops only if the brood is physiologically stressed in some way like chilling (Root, 1990) and it is documented that diseases of fungal origin are more prevalent in dump and cool conditions (Gochnauer *et al*., 1975).

In Ethiopia, the existences of two adult honeybee diseases (*Nosema apis* and *Melpighamoebae mellificae*) and their distribution was studied and reported (Gezahegn and Amsalu, 1991; Desalegn and Amsalu, 1999). However, until now there has not been any record on the existences of honeybee brood diseases in Ethiopia. The clue at Holotta apiary & complaints from farmer beekeeper for chalk brood disease necessitated this rapid survey. This paper reports results of a study designed to assess & confirm the occurrence of chalk brood in honeybees in Ethiopia.

Materials and Methods

The survey transects and the beekeepers were selected randomly. Simple survey was made around Holetta on an individual farmer beekeepers' colony and at Gedo demonstration site, which is located at about 190 km west of Addis Ababa. An area covered in the study is shown in Figure 1.

Sampling was done following the brood season (October-January 2001). Thirteen-survey sites consisting of 276 bee colonies were inspected externally and internally for the sign of chalk brood disease.

In this study, particular attention was given to detect the colonies in each apiary only for the presence of chalk brood sign. Sign of chalk brood (dead infected larvae left uncapped by nurse bees in the comb cells, and mummies at the hive entrances, on the hive floor and on the ground perpendicular to the hive opening) were thoroughly observed. From the inspected thirteen apiary sites, dead & dry larvae (suspected black mummies larvae dead of chalk brood) were collected only from eight apiaries based on the clue signs of the disease.

Figure 1 Areas (shadow part) covered in the study

Entirely, 240 such dead & dry larvae of honeybee larvae from 48 bee colonies (5 per colony) were collected. The dead & dry larvae of honeybee larvae collected from each site were separately macerated in sterile mortar with distilled water to prepare suspensions containing *A. apis*. The suspensions were filtered separately through fine cloth and the fungus was grown in laboratory on Potato Dextrose Agar (PDA) containing antibiotic (to avoid any bacterial contamination) on a petri dishes (Spiltoir and Olive, 1955; Bailey, 1981). Microscopic examination of the culture was done after 8 days for the spore cysts and spore balls size of *A. apis* adopting (Spiltoir and Olive, 1955; Bailey, 1981 Skou, 1972; Bissett, 1988). Photographs of the affected brood combs and fungus culture were taken.

Results

Microscopic examination of the culture revealed that the range of the size of the spore cysts and the spore balls were 40-89µ & 7.2-17.8µ, respectively (Table 1). From the 13 inspected apiaries, 8 of them (61.5%) were found positive to the chalk brood causing *A. apis* (Table 2). From the 8 infected apiaries, 48 of the 162 (29.6%) bee colonies inspected were found tainted with chalk brood fungus (*A. apis*). The prevalence of the fungus among the apiary sites ranged from 0% to 100%, with an overall average of 17.4% (Fig. 2).

All colonies that were infested with chalk brood fungus (*A. apis)* have revealed signs of the disease either externally or internally. Internally, chalk brood affected broods were found dead & uncapped in the chalk brood affected brood comb cells (Fig. 3). While in the severely affected colonies, dead & black larvae mummies (Figures 4 & 5) were found on the bee hive land boards & on the ground perpendicular to the hive entrances externally. The disease was in particular rigorous and widely distributed in two apiaries (Fig. 2), which are owned by private beekeepers and in the radius of 5-10 km from Holetta Bee Research Center. The survey time, observation and reports from beekeepers, and experts affirmed that much of the affected broods were drones broods in the month of October.

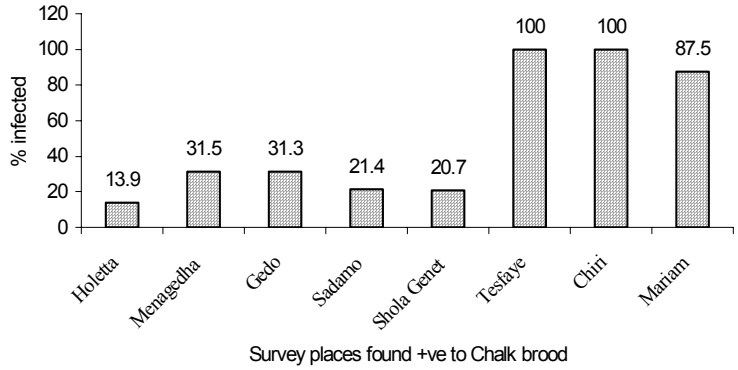

Figure 2. Percent of infestation level among apiaries that were positive to *A. apis*

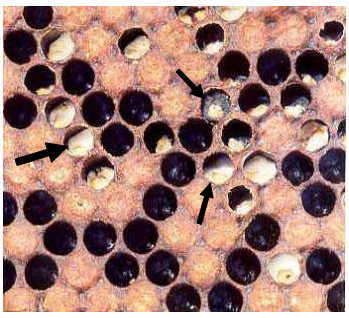

Figure 3. Chalk brood affected brood in a comb cell

Figure 4. Chalk brood mummies

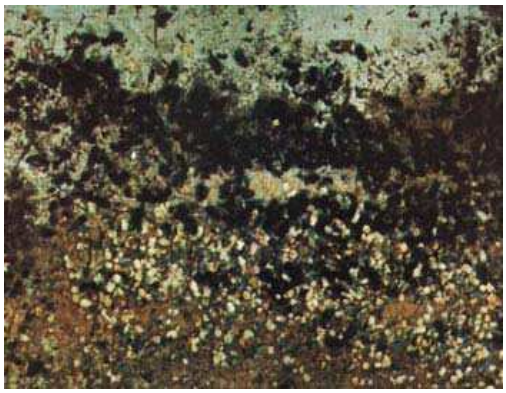

Figure 5. Chalk brood affected larvae black mummies

Discussion

Microscopic examination of the culture revealed that the range for the size of the spore cysts and the spore balls is 40-89µ & 7.2-17.8µ, respectively. Both measurements fall in the standard size ranges described for *A. apis* (45-119µ & 7-18µ in that order) by Spiltoir & Olive (1955), confirming the occurrences of the pathogen (*A. apis*) in Ethiopia.

As the main purpose this work was only to detect if chalk brood is present or not, no attention was given in the process to compare infestation level among each colony in the same apiary, nor among the bee colonies at different apiaries.

Both the secondary information collected from the farmer beekeepers & the experts, and the primary data collected in this work indicated that the chalk

brood disease occurs in the October month in which the ambient temperature sometimes goes below zero. This is concurrent with the investigation by Gochnauer *et al.* (1975) & Root (1990), who reported that diseases of fungal origin are more prevalent in dump and cool conditions and aggravates when the brood is chilled.

Table 1. Microscopic measurements taken after laboratory culturing of *A. apis* spore

No	Parts measured	Measurement taken from the culture
1	Spore cysts	40-89 µ
2	Spore balls	7.2-17.8 µ

Table 2. Total bee colonies diagnosed, number of colonies found positive & percentage infection across the inspected sites

No	Apiary Site	Number of inspected colony	Number of infected colony
1	Holetta	36	5
2	Menagedha	54	17
3	Gedo	16	5
4	Suba	42	0
5	Geresu	18	0
6	Sadamo	14	3
7	Roge	25	0
8	Rob Gebeya	24	0
9	Gelgel	5	0
10	Shola Genet	29	6
11	Tesfaye	4	4
12	Chiri	1	1
13	Mariam	8	7
	Total	276	48

In the bee colonies seriously affected with chalk brood disease, complete terminate of drone brood rearing accompanied with dismantling and frequent clearing of such type of larvae and pupae was observed. This investigation agrees with findings by Gochnauer *et al.* (1975) who established chalk brood disease on the outer fringes of the brood combs, which affects drone broods more commonly than others. According to Gochnauer *et al.* (1975) when colony become cluster due to cool temperature, the population of adult bees is not sufficient enough to maintain ideal brood temperatures particularly on the outer periphery of the brood.

The engagement of the bees in dismantling and clearing of the drone larvae and pupae seems the bees' natural way of choosing between the worker and the drone broods under adverse condition. The assumed reason for the choice to be taken is that the bees give more precedence to broods developing to worker bees (replacement stocks) than broods developing to drone bees

(meant for breeding & contemplated only under normal situation). Thus, chalk brood disease is most likely to appear in brood left unprotected by the cluster, which usually includes the drones (Gochnauer *et al*., 1975).

Conclusion

This study coupled with the recent reports from different beekeepers & experts indicate that chalk brood disease of honeybees is becoming a threat to the apiculture sub-sector in Ethiopia. Therefore, attention should be given to investigate its ecology, magnitude of distribution and effect under the prevailing local conditions to propose all rounded control and prevention before it advances beyond control.

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Eth. J. Anim. Prod. 6(1) - 2006: 9-17

Seasonal Changes in Testis Size and Semen Characteristics of Horro Rams

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Abstract

Fifty-two mature Horro rams (3-years of age) were used to study the effect of season on testis size, semen traits and sexual performance for a period of one year. Depending on the amount of rainfall, the experimental period was classified into four seasons, March to May (season 1), June to August (season 2), September to November (season 3), and December to February (season 4). The semen ejaculates were collected fortnightly using Artificial Vagina (AV) and subjected to evaluation by inspection and microscopic examination. Data were analyzed by General Linear Model Procedure of the Statistical Analysis System (SAS, 1996). Simple correlation analysis was also used to determine the interrelationship between relative humidity (%), air temperature (°C), testis and semen traits considered. Season had significant ($P<0.001$ to $P<0.05$) effect on scrotal circumference (SC), libido (LI), testicular diameter (TD), semen density (SD) and semen motility (SM). Body condition had significant effect ($P<0.05$) on TD and semen volume (SV); while body weight significantly affected SC and TD ($P<0.001$) and LI ($p<0.05$). It was observed that SC of the rams was higher from December through May and lower from June to November. Semen quality and libido of rams were highest from September through January and lowest from March to May. But SV was almost constant throughout the year. Therefore, under controlled mating system, September to January is the recommended mating season at Bako and other areas experiencing similar weather conditions in order to benefit from the superior reproductive performance of rams.

Keywords: Horro rams, libido, season, semen traits, testis size.

* Corresponding author

Introduction

In any enterprise concerned with breeding of livestock, the male animal represents half of the reproductive potential of the herd or flock. If there are insufficient males, or if their fertility is in any way impaired, then these factors will be reflected in reduced fecundity in the female animals (Maclaren, 1988). Therefore, in order to increase flock fertility, improve the genetic merit of a flock and to reduce the number of breeding males, rams with superior reproductive traits are required (Mukasa-Mugerwa and Ezaz, 1992).

Seasonal influence on the quality and quantity of sperm produced in rams has been reported (Galal *et al*., 1978), and thus seasonal differences in fertility (Schoeman and Combrink, 1987; Mukasa-Mugerwa and Ezaz, 1992) and testicular size or sperm output was found to be associated with nutrition (Oldham *et al*., 1978). Small scrotal circumference, poor quality semen and lack of libido are reported to be major causes for variation in flock fertility (Venter *et al*., 1984), and are also found to be varying across seasons of a year. Though photoperiodism is minimal in the tropics, seasonal variations in climatic variables and feed availability do exist and it is important to know the appropriate time of breeding. Thus, this study was carried out to investigate the effect of season on testis size, semen traits and sexual performance of Horro rams so as to decide the appropriate mating season.

Materials and Methods

Study area

The study was conducted at Bako Agricultural Research Center, located at about 250 km west of Addis Ababa and some 3 km from the main road to Nekemte. Bako is situated at an altitude of 1650 meter above sea level (9º 06' N and 37º 09' E). The climate is hot and humid with a mean annual rainfall of 1219 mm. More than 80% of the rainfall is recorded in the months of May to September. Mean monthly minimum and maximum temperatures are 14°C and 28°C, respectively, with an average monthly temperature of 21°C. The daily mean minimum and maximum temperatures are 9.4°C and 31.1°C, respectively. Potential evapotranspiration averages 62 mm per month.

Study animals and data collection

Fifty-two mature Horro rams (3-years of age) were selected from the main flock in the center and used to study seasonal influence on testis size, semen traits and sexual performance from March 2000 to February 2001. The animals were exclusively maintained on pasture, grazing for 8 hrs a day

(9:00a.m to 5:00p.m) with no supplementary feed at night. Depending on the amount of rainfall, the experimental period was classified into four seasons, March to May (season 1), June to August (season 2), September to November (season 3), and December to February (season 4). The amounts of rainfall (mm) recieved during the different seasons were 130, 215, 132, and 8.3, respectively. Average relative humidity (%) and mean temperature (°C) of each season were also recorded to look into their relationships with semen and testis traits.

Liveweight was recorded on all rams, to the nearest 0.5kg, at the beginning and subsequently at fourteen days interval throughout a year. Body condition score (scale: 0-5; where 0=starving, 1=very thin, 2=thin, 3=moderate, 4=fat, 5=very fat) was done according to (Hossamo *et al.*, 1986) by assessing of several aspects of the tissue covering the backbone and the transverse and the spinous processes in the loin region (lumber vertebrae) between the last rib and the pelvis. Semen was collected by artificial vagina technique fortnightly during the study period. The volume of the ejaculate semen was read to the nearest 0.1ml directly from a graduated collection tube. Consequently, sperm cell count was done using microscope at 40X magnification after diluting the semen samples with 4% (NaCl) saline solution, in serial dilution method. Sperm concentration per milliliter was determined by the formula equals to number of sperm in 16 small squares x 5000 x dilution rate.

Semen density was scored visually on a 0-5 scale on the basis of sperm cell concentration and color of sperm cells. Mass motility was scored subjectively on a 0-5 scale on the basis of wave motion readings from a microscope at low (10x10) magnification. Libido was scored as described by Chennoweth *et al.* (1984) using 0-9 scales on the basis of behavioral expression of the animals for service as 0 = ram showed no sexual interest or no mount; 1= one mount or mounting attempt, no service; 2 = Two mounts or mounting attempt, no service; 3 = More than two mounts or mounting attempt, no service; 4 = Two mounts, one service followed by sexual interest including mounts and mounting attempts; 5 = More than two mounts or mounting attempts and one service followed by sexual interest; 6 = Two mounts or mounts and one service, no further sexual interest; 7 = One mount and one service, no further sexual interest; 8 = One mount and one service followed by sexual interest including mounts and mounting attempts; and 9 = More than two mounts and one service, no further sexual interest.

Scrotal circumference was measured as described by other authors (Schoeman and Combrink, 1987; Mukasa-Mugerwa and Ezaz, 1992; Yohannes *et al*., 1995; Solomon and Thwaites, 1997). The testes were brought firmly and evenly to the bottom of the scrotum until the ventral skin folds were eliminated. The testes were then held firmly in place by grasping the neck of the scrotum with one hand above the heads of the epididymis. The opposite hand then guided a flexible tape upward from the bottom of the scrotum. Then the measurement of scrotal circumference was taken at the greatest testis circumference.

Testis diameter was measured using a caliper at the anterior-posterior position on each testis at its maximum width as described by Schoeman and Combrink (1987). The method described by the same authors was used to correct testis diameter for scrotal thickness by subtracting twice the skin thickness from the measured testis diameter. The mean values of both right and left testis diameter were taken as the testis diameter for an individual animal.

Data analysis

The General Linear Model Procedures of the Statistical Analysis System (SAS, 1996) was used to analyze the data. The dependent variables were scrotal circumference (SC), testis diameter (TD), libido (LI), semen motility (SM), semen density (SD) and semen volume (SV). Season (4 levels) was fitted as fixed effect. Body weight and body condition score were fitted as linear covariates. Pearson's correlation coefficient was used to examine and determine the interrelationships between relative humidity (%), air temperature (°C), and semen and testis traits.

Results

Analysis of variance and least squares means (±SE) of SC, TD, LI, SD, SM and SV at different seasons are shown in Tables 1 and 2, respectively. Season had significant effect ($p<0.001$) on SC and TD. Significant difference was observed in SC between season 1 and seasons 2 and 3, but not between season 1 and 4. SC was significantly higher during seasons 1 and 4. TD was significantly different between season 1 and seasons 3 and 4, but not between season 1 and 2. It was higher during seasons 1 and 2.

SD and SM were significantly ($p<0.05$) affected by season. Significant difference was observed in SD between season 1 and 3, 1 and 4 whereas, SM was significantly different between season 2 and 3, and 2 and 4. SD and SM

were higher in seasons 3 and 4. SV was not significantly (P >0.05) different between seasons in the present study.

The LI of the ram was also significantly (p < 0.01) influenced by season. The significant difference in LI was observed between season 1 and 3, 1 and 4, and 2 and 4. Higher LI was recorded during seasons 3 and 4.

Body weight had significant effect on SC and TD (P< 0.001) and LI (p<0.05) while body condition significantly affected TD and SV (p<0.05).

The correlation coefficients among testis measurements and body weight, body condition score, air temperature and relative humidity are presented in Table 3. The correlation between body weight and body condition, SC, TD, and LI were positive and high. SC had a positive and high phenotypic correlation with TD and LI, but the magnitude of estimates between SC and relative humidity was low and negative. Positive but low correlation coefficients were found between air temperature and SC, TD, and SM, but air temperature was negatively correlated with LI, SV and SD. SM had high and positive correlations with LI and SD.

Table 1. Analysis of variance and level of significance of scrotal circumference (SC), testicular diameter (TD), libido (LI), semen volume (SV), semen density (SD) and semen motility (SM) as affected by season, body condition (BC) and body weight (WT)

Variable	Mean squares of			R^2	CV	EMS	Overall mean
	Season	BC	WT				
SC	26.23***	0.78	38.53***	0.39	5.88	1.69	28.76
TD	0.59*	1.67**	3.08***	0.29	7.30	0.44	6.05
LI	39.16**	6.46	40.75*	0.09	95.26	3.07	3.23
SV	0.16	0.79*	0.31	0.05	49.88	0.39	0.79
SD	2.47*	2.26	0.12	0.05	22.49	0.92	4.08
SM	6.93*	0.05	1.48	0.04	39.09	1.57	4.02

***= p <0.001, **= p <0.01, *= p <0.05, R^2=Coefficient of Determination, CV=Coefficient of Variation

EMS=Error Mean Square

Table 2. Least squares means (±SE) for scrotal circumference (SC), testicular diameter (TD), libido (LI), semen volume (SV), semen density (SD) and semen motility (SM) of Horro rams at different seasons of a year.

Season	SC (cm)	TD (cm)	LI (score)	SV (ml)	SD (score)	SM (score)
1(Mar to May)	29.0±0.09^{a}	6.1±0.02^{a}	2.8±0.17^{a}	0.7±0.05	3.8±0.10^{a}	3.9±0.17^{a}
2(June to Aug)	28.6±0.12^{b}	6.1±0.03^{ab}	2.9±0.21^{ab}	0.8±0.07	4.1±0.17^{ab}	3.4±0.28^{ab}
3(Sept to Nov)	28.3±0.12^{b}	6.0±0.03^{b}	3.4±0.19^{bc}	0.9±0.05	4.3±0.12^{b}	4.3±0.21^{ac}
4(Dec to Feb)	28.9±0.09^{a}	6.0±0.02^{b}	3.7±0.18^{c}	0.8±0.04	4.2±0.10^{b}	4.2±0.17^{ac}

Within column means with different superscripts differ significantly (p<0.05)

Table 3. The correlation coefficients among scrotal circumference (SC), testicular diameter (TD), libido (LI), semen volume (SV), semen density (SD) and semen motility (SM) with body weight, body condition, air temperature and humidity.

Traits	WT	SC	TD	LI	SV	SD	SM	Air Temp	Relative Humidity
BC	0.44***	0.24***	0.29***	0.13***	0.11	-0.12	-0.06	-0.27***	0.31***
WT		0.62***	0.54***	0.27***	-0.06	-0.09	-0.06	-0.07*	0.06*
SC			0.71***	0.20***	-0.11	-0.11	-0.14*	0.07*	-0.08**
TD				-	-0.16	-0.15	-0.17*	0.06*	0.05
LI					-	-	0.22***	-0.003	0.004
SV						0.29**	0.20	-0.19*	0.10
SD							0.33***	-0.02	0.01
SM								0.03	-0.06
Air Temp									-0.83***

***= $P<0.001$, **= $P<0.01$, *= $P<0.05$

Discussion

The low measurement of SC during season 2 might be attributed to a decline in the condition of the animals as a result of parasitic burden in this particular season. Despite the poor grazing condition in the dry season, the high parasite infestations of the pasture during the wet season (Muktar *et al.*, 1993) and the low minimum temperature may negatively affect the animals (Solomon *et al.*, 1995). The reason why low SC measurements were found during season 3 is difficult to explain, but there might be low minimum temperature during this particular season which makes the testis to be closer to the body. Froman and Kirby (2000) reported that scrotum provides a cooling apparatus essential for spermatogenesis to occur in domestic animals at 32 to 35 °C.

The effect of season on TD might be a reflection of differences in feed availability between seasons, caused by differences in rainfall. Oldham *et al.* (1978) and Master and Fels (1984) reported that testes seem to be particularly sensitive to changes in nutrition as rams both gain and loss testicle volume at a greater rate than liveweight.

SD and SM were also significantly ($p<0.05$) affected by season. In the current study, SD and SM were higher in seasons 3 and 4. Though no clear reason could be given for the better quality of semen in season 4, the better quality of semen in season 3 might be attributed to the availability of feed (especially crop aftermath). Nevertheless, Rege *et al.* (2000) reported that semen collected in the dry season had higher frequency of spermatozoa abnormalities than that collected in the wet season. According to these

authors, ejaculates obtained during the dry season tended to have higher concentration of spermatozoa, which were also more motile. The same authors reported that mass motility of sperm cell increases as concentration increases while higher concentration of spermatozoa is expected to result in a higher wave motion score compared to lower concentration of spermatozoa of the same individual motility.

SV was not significantly ($p>0.05$) different between seasons and it is in agreement with results reported by Rege *et al*. (2000). In the present study, higher LI was recorded during seasons 3 and 4, which could be partially explained with relative availability of adequate feeds (crop aftermath) in season 3. Asfaw *et al.* (1997) also reported an environmentally controlled seasonality of mating in which peak mating time tends to follow the availability of adequate feeds. According to these authors, this time corresponds with immediately following crop harvest that allows free access to the aftermath of different crops. The better LI observed during season 4 might be due to the higher concentration of spermatozoa, which were more motile during the dry season. Rege *et al.* (2000) also reported that ejaculates obtained during the dry season tended to be more motile than those collected during the wet season.

In the present study, body weight had significant effect on SC and TD ($P< 0.001$) and LI ($p<0.05$) and the influence of body weight on testis measurements was in agreement with those reported by (Schoeman and Combrink, 1987; Mukasa-Mugerwa and Ezaz, 1992; Yohannes *et al*., 1995). Yohannes *et al*. (1995) also reported that TD and SC are positively and strongly related to body weight in Horro sheep.

Conclusion

It was observed that semen quality and LI of Horro rams were highest from September through January and lowest from March to May. But SV was almost constant throughout the year. Therefore, under controlled mating system, September to January is the recommended mating season at Bako and other areas experiencing similar weather conditions in order to benefit from the superior reproductive performance of rams.

Acknowledgement

The authors wish to thank Mr. Berhan Feleke and Mr. Berhanu Soboqa for their assistance in flock management and data collection during the study period.

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Effect of Season and Supplementation on Semen and Testicular Characteristics of Horro Bulls in Sub-Humid Environmental Condition in Ethiopia

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Abstract

A total of 32 mature Horro bulls from Bako Agricultural Research Center were used with the main objectives of determining the effect of season and supplementation on semen and testicular characteristics. The season was classified as dry (October-April) and wet (May-September). The bulls were randomly divided in two groups: supplemented and non-supplemented of 16 animals each. Data were analyzed using the repeated measure analysis of variance procedure of SAS (SAS, 1994). The supplemented group was offered a supplementary feed at a rate of 1.5kg/bull/day. Results showed that supplementation did not affect most of the semen and testis characteristics except for semen volume and semen concentration (only at certain time of the experimental period). However, there was a general tendency for the bulls from the supplemented group to maintain higher sperm concentration (330.4±23.6 and 623.2±66.8x10^6ml for the supplemented group and 333.8±23.6 and 564.2±69.1x10^6ml for the non-supplemented group) and higher sperm motility as compared to those of non-supplemented group (2.6±0.2 to 3.6±0.2 for the supplemented group and 1.7±0.2 to 3.0±0.3 for the non-supplemented group). Week of semen collection significantly ($p<0.05$) affected the sperm mass motility of both groups only during certain weeks of the year. A significant interaction effect ($p<0.05$) between week (time) and supplementation was also observed on semen motility. Week (time) and time by supplementation interaction affected ($p<0.05$) testis volume and scrotal skin thickness only at certain time of the experimental period.

Keywords: Horro bulls, season, semen, sub-humid environment, supplementation, testicular characteristics

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Introduction

Semen production, as reflected by semen volume, in bulls is influenced by nutrition. It is a good indicator of the sperm quantity that can be produced. Semen volume is also highly correlated with testis volume. Environmental variables and other fixed effects like season, temperature fluctuations, breed and age are reported to affect testis volume (Patel *et al*., 1988; Singh and Pangawkar, 1989; Mohanty *et al*., 1991; Nwakalor and Obasi, 1991). Hormonal abnormalities, seasonal changes, testicular degeneration and disease could also affect ejaculate volume in bulls (Galina and Arthur, 1991, Salah *et al*., 1992, Stalhammar *et al*., 1994, Rode *et al*., 1995). Let alone among different bulls, considerable fluctuation exists in ejaculates from the same bulls, especially during periods of warm weather. High summer temperatures generally decrease the volume and the number of spermatozoa per ejaculate. Sperm motility is also extremely susceptible excessive heat or cold. Sperm motility is an indicator of the ability of sperm to move forward to the ovum after ejaculation (Hafez and Hafez, 2000). Factors such as time of the day, temperature, semen concentration, contamination and the method of semen collection all affect the motility score (Belorkar *et al*., 1990; Osman *et al*., 1990; Singh and Sharma, 2001).

Scrotal circumference, which is an indicator of testis size, is highly correlated with sperm production and semen quality (Ott, 1991; Brinks, 1994). It is an easily measurable, highly repeatable trait with high heritability (Bellows and Staigmillar, 1994). The importance of scrotal circumference as an indicator of fertility of bulls was reported in the literature (Glauber *et al*., 1990; Tegegne *et al*., 1992; Brinks 1994; Rocha *et al*., 1994; Silva-mena *et al*., 2000). A strong relationship exists between plane of nutrition, body weight and scrotal development (Venter *et al*., 1977; Rekwot *et al*., 1988; Tegegne *et al*., 1992). Thus, this study was intended to investigate the effect of season and nutritional supplementation on semen and testicular characteristics of Horro bulls in sub-humid environmental condition in Western Ethiopia.

Materials and Method

Location of the study

The study Center, Bako, is situated in East Wollegga zone, about 250 km west of Addis Ababa on the main road to Nekemte at an altitude of approximately 1650 m above sea level (09° 06´ N and 37° 09´ E). Bako has a hot and humid climate and receives a mean annual rainfall of about 1219 mm,

more than 80 % of which is recorded in the months of May to September. Mean monthly maximum and minimum temperatures are 28°C and 14°C, respectively, with 21°C of average temperature. Potential evapotranspiration averages 62 mm per month.

Management of the experimental animals

Thirty-two mature Horro bulls of about 6 years of age with average body weight of 211kg were used to investigate the effect of nutritional supplementation and seasonal variation on semen and testicular characteristics between February 2001 and January 2002. The bulls were randomly divided in to two groups. The supplemented group was given a concentrate ration (consisted of 20% crude protein) composed of ground maize, oil cake meal (*Guizotia abyssinica*), bone and blood meal at a rate of 1.5kg/bull/day. The supplementation was offered early in the morning (07:00), before the bulls went out for grazing. During the day, both the supplemented and non-supplemented groups were maintained on natural pasture for approximately 8 hours per day (08:00 to 17:00). They were housed in individual pens at night.

Semen collection methods

Semen was collected from each bull using an electro-ejaculator (Eltro11 type), manufactured in South Africa by Electronics Research group. The collection was performed every 2 weeks all the way through the 50 weeks investigation period and each semen collection was performed between 09:00 and 12:00.

Semen volume and colour

The volume of the ejaculate was recorded immediately after collection by reading the calibrated collection test tubes used to collect the ejaculate from the funnel shaped rubber cone. The colour of the ejaculate (creamy, milky or watery) was recorded as an indicator of the semen density and the possibility of semen contamination.

Sperm mass motility and concentration

The sperm mass motility was assessed and recorded immediately after collection. The ejaculate was assessed microscopically (x 1000 magnification) and a value allocated on a subjective scale of 0 to 5 (Elmore, 1985). Sperm concentration determinations were performed using a hematocytometer (Improved Neubaner, Marianfeld, Germany) to calculate the density or concentrations of the ejaculate ($x10^6$/ml) (Elmore, 1985).

Staining techniques

One drop of semen sample was mixed with 2 to 3 drops of eosin-nigrosin stain on clean slide. About 200 spermatozoa were evaluated in different fields to determine percentage dead or live spermatozoa. Live spermatozoa appeared unstained while dead spermatozoa appeared stained with brownish purple background.

Scrotal circumference

Scrotal circumference (SC) of each bull was measured with a measuring tape placed around the broadest part of the scrotum. These measurements were recorded every second week, for the fifty weeks trial period.

Testis volume

Testicular volume was determined as described by Lodge and Salisbury (1970) and Mohanty *et al.* (1991) by submerging the entire scrotum containing the testis up to the basis of the neck of the scrotum in a calibrated plastic bucket filled with water. The quantity of water displaced by the submerged scrotum containing the testis was recovered and measured in a graduated cylinder as an estimate of the testis volume. The testicular volume was measured from the rear, between bulls' legs while standing. These measurements were taken at the same time every second week (09:00 to 11:00am).

Scrotal Skin Thickness

Scrotal skin thickness is generally measured as possible indicator of subcutaneous fat deposition around the testis. The scrotal skin thickness was measured fortnightly with the aid of the caliper. It was measured in the middle of the right lateral side of the scrotum and the scrotal skin was folded, then the value of the measured skin fold thickness was divided in to two to get the scrotal skin fold thickness.

Data analysis

The repeated measure analysis of variance procedure of SAS (SAS, 1994) was used to analyze the data. Correlation coefficients were also determined using the same software.

Results and Discussion

Semen volume

Season of the year did not have significant effect on semen volume (Fig 1). Except for the first couple of weeks from the onset of the experiment, semen

volume did not differed significantly between the two treatment groups. However, throughout the study period, there was a tendency for animals in the supplemented group to have higher ejaculate volume compared to the non-supplemented group. Ejaculate volume of the supplemented bulls increased until about week 8 after which it remained relatively constant until about week 37 where after it decreased. Even the high ambient temperature experienced during summer (October to April) did not affect semen volume.

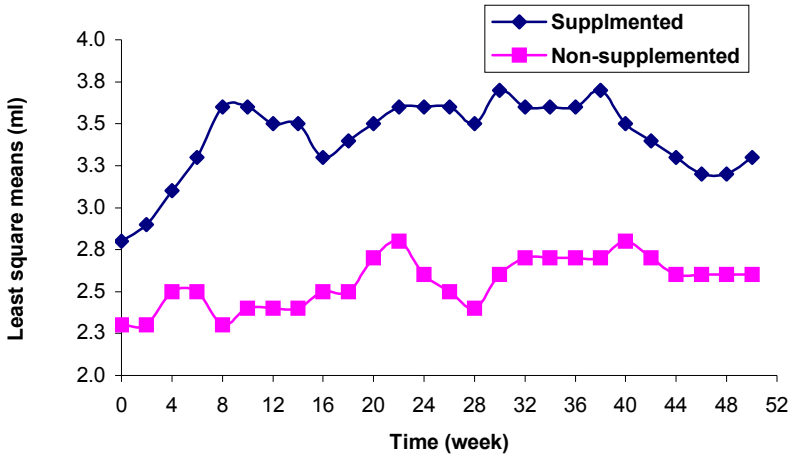

Fig 1. Least square means of semen volume of Horro bulls

As expected, level of nutrition has irregularly affected semen volume (P<0.05). The supplemented group recorded higher semen volume than the non-supplemented group. The present result is not in agreement with the findings of Smith and Merilan (1991) who reported that supplementation did not have any significant effect on semen volume in Holstein bulls. However, other researchers reported that level of nutrition could influence semen production, as reflected by semen volume or ejaculate volume in bulls.

The mean semen volume recorded in the present study (2.8±0.3 to 3.7±0.1ml for the supplemented and 2.3±0.3 to 2.8±0.1ml for the non-supplemented bulls) was lower than that reported by Shelke and Dhami (2001) for Gir bulls (*Bos indicus*) (4.8±0.2ml). Silva-Mena *et al*., (2000) also reported a mean semen volume of 6.3±1.2 and 5.9±0.8ml for the Brahman and Nelore (zebu) bulls in India, respectively. These differences could be attributed either to

the method of semen collection or breed differences. Artificial vagina has been proven to be a more desirable semen collection technique when compared to electrical stimulation in bulls. When semen is collected by means of electrical stimulation the sample obtained is often of inferior quality.

Semen color

During the observation period three semen colour types namely; creamy, milky white and a watery appearance were observed. The majority of the semen samples were in the range of creamy to milky white colour. Herrick and Self (1962) reported that some bulls (up to 10%) produce semen which is normally yellow in colour. This should not be confused with semen that was yellowish colour that could be due to riboflavin pigment that is normal characteristics in certain bulls. The three colour types observed during the current study were creamy, milky white and watery. The watery colour observed in the present study was probably due to excessive stimulation of the accessory sex glands (Hefez and Hafez 2000). In this study, semen from the nutritionally supplemented group tended to be creamier than the non-supplemented group, which is an indicator of higher sperm concentration.

Sperm motility

Week of collection significantly ($P<0.05$) affected the sperm mass motility for both the supplemented and non-supplemented bulls during certain weeks of the year. This could be attributed to the effect of season and or the interaction between season and nutritional management. However, no clear seasonal trend could be observed (Fig 2). There was a tendency for the supplemented bulls to have a higher sperm mass motility during most of the observation period (until about week 37) as compared to the non-supplemented bulls.

Time x treatment interaction also showed a significant ($p<0.05$) effect on sperm mass motility. These results are in agreement with those reported by Belorkar *et al.* (1990), Osman *et al*. (1990) and Singh and Sharma (2001) who found time, ambient temperature, concentration and contamination to have significant effects on sperm mass motility in bulls. In the present study, a decreasing trend in terms of mass motility was observed between weeks 37 to 44 both in the supplemented and the non-supplemented bulls which is not in agreement with the findings of Alvarez *et al*. (1995) who reported that sperm motility increases with increasing age of the animals. The reason for

the decrease is unclear, but may possibly be attributed to season, which in turn could be associated with feed availability since the experimental animals were mainly maintained on natural pasture. The low motility score at the end of the experiment (summer) could also be attributed to the high ambient temperature that could negatively affected sperm motility. Sperm motility is extremely susceptible to environmental conditions such as excessive heat or cold (Belorkar *et al*., 1990; Osman *et al*., 1990). Hafez and Hafez (2000) reported that malnutrition, particularly low energy intake could reduce growth rate, delay puberty and permanently impair semen output. All those factors are associated with a reduction of sperm motility.

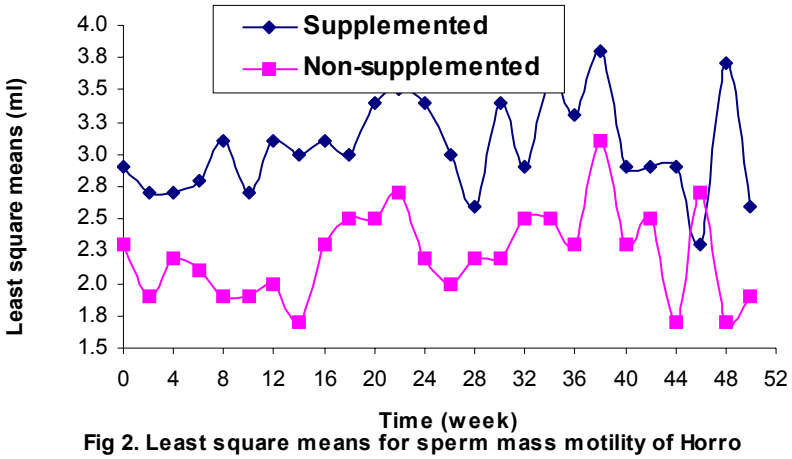

Fig 2. Least square means for sperm mass motility of Horro bulls

Sperm concentration

The time (week) when semen was collected did not have significant effect on sperm concentration (Fig 3). Nevertheless, the sperm concentration of the supplemented group tended to remain higher than those of the control group. Throughout the study period, except for weeks 4, 32, 44 and 48, where the difference between the two groups were significant (P<0.05), no significant differences were observed. During these periods, sperm concentration of the non-supplemented bulls was relatively inferior. Sperm cell concentration is generally expressed as the number of cells per ml (Hafez and Hafez 2000). The average sperm concentration in bulls ranges from 800 million to ½ billion per ml. in bulls. Differences in sperm concentration have been attributed to the feeding regime, season of the year and for different geographic localities (Lodge and Salisbury, 1970). The values of sperm concentration of the current

study (ranged from 330.4±23.6 to 623.2±66.8 10^6/ml for the supplemented bulls and from 333.8±23.6 to 564.2±69.1x10^6/ml for non-supplemented bulls) were lower than the findings of Shelke and Dhami (2001), who reported that the sperm concentration to be 1219.4±38.2x10^6/ml in Gir bulls. The values are, however, comparable with those of Brahman and Nelore (577.2±83.4x10^6/ml and 621.7±92.5x10^6/ml, respectively) reported by Silva-Mena *et al.* (2000). The lower sperm density in the present study may partly be explained by the collection techniques used. The density or sperm concentration of the ejaculate collected by means of an artificial vagina has been found to be significantly higher as compared to that of electro-ejaculator (Amann, 1970).

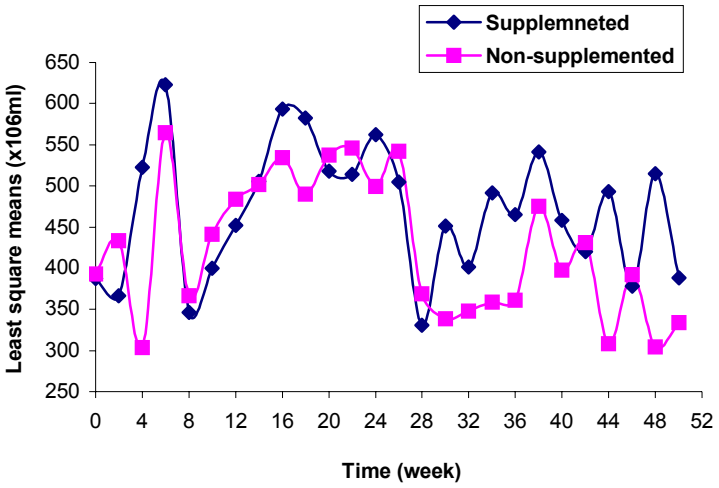

Fig 3. Least square means of sperm concentration of Horro bulls

Scrotal circumference

Both week of measurement and supplementation had no significant effect on ($p > 0.05$) scrotal circumference. The mean scrotal circumference of the bulls, in both treatment groups, tended to increase throughout the study period (Fig 4). Godfrey *et al.* (1990) reported marked seasonal fluctuations in testis size that size of the testis increases during the summer and decreases during the winter. Many factors, such as breed, age, season and body mass influence testis size or scrotal circumference. According to Makarechian *et al.* (1984), though testicular size in bulls is an inherited trait it could be influenced by age and pre-weaning and feedlot growth rate of the animals. The most significant testicular growth in bulls occurs from the age of 6 to 36

months and can be monitored by measuring the scrotal circumference (Mukasa-Mugerwa and Ezaz, 1992). According to these authors, maximum testicular size usually occurs at 4 to 6 years of age. The mean scrotal circumference of bulls used in the present study was almost similar throughout the study period. The mean scrotal circumference of the bulls (ranged from 28.8±0.5 to 33.0±0.2cm) used in the present study was comparable with the value reported for Fulani (Bonagi) cattle (30.8cm), but larger than the 22.3cm reported for N'Dama bulls (Nwakalor and Obase, 1991).

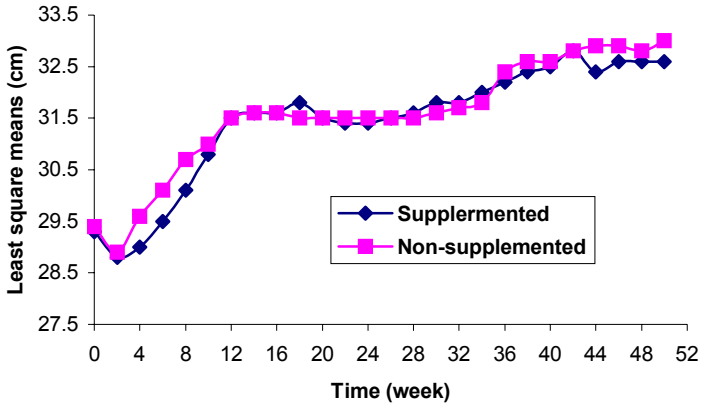

Fig 4. Least square means of scrotal circumference

Concentrate supplementation did not have effect on the scrotal circumference of bulls. The non-significant differences obtained between the supplemented and control bulls in scrotal circumference is contrary to the findings of Rekwot *et al*. (1988) and Venter *et al*. (1977), who reported a strong relationship between level of nutrition and scrotal development. In the current study, the reason for the absence of evident differences between the supplemented and the control groups could be either the treatment period too short or the nutrition supplemented was not adequate.

Testis volume

The time during when testis volume was measured showed significant ($p<0.05$) changes at certain stages (Fig 5). Though, testis volume of both the supplemented and non-supplemented groups gradually increased from the onset to the end of the study period, those of the supplemented group

increased more until about week 20. Testis volume is correlated with semen quantity and acts as a good indicator of semen quality (Herrick and Self, 1962). Patel *et al.* (1988) have reported effects of season, breed and age on testes volume, and was related with an increase in body weight and age of bulls. The significant (P<0.05) influence of time on testicular volume recorded during the study period may suggest that as time progressed body weight of the bulls has a subsequent effect on testes volume.

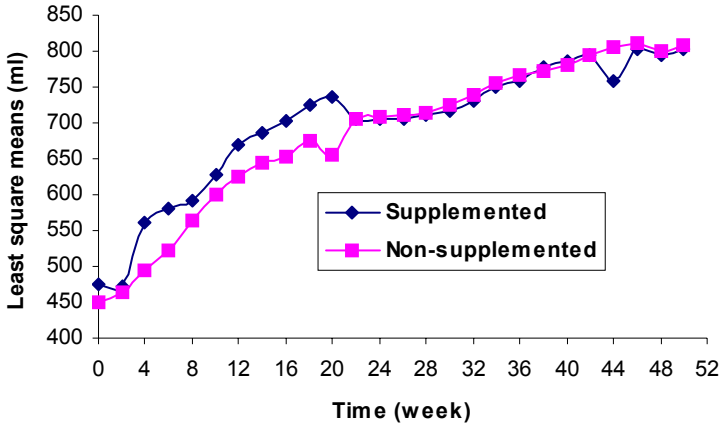

Fig 5. Least square means of testis volume of Horro bulls

A significant (P<0.01) time x treatment interaction on testis volume was recorded in this study and it could imply a specific influence of nutrition on body weight and testis volume. The testis volume for the supplemented group of bulls increased from 478.1 ± 20.6 to 801.9 ± 4.8 ml, while that of the control group increased from 449.4 ± 20.6 to 808.1 ± 4.8 ml. No advantage of nutritional supplementation was observed regarding testis volume. This result is not in agreement with the findings of Singh and Pangawkar (1989), who demonstrated a beneficial effect of nutrition on testicular growth in bulls. The absence of differences between the two groups may indicate that either the supplementation level was not sufficient to affect testicular growth or the treatment period was not long enough to induce differences between the two groups.

Scrotal skin thickness

Scrotal skin thickness was measured as a possible indicator of fat deposition under the scrotal skin (Tomar *et al*., 1965). The scrotal skin thickness was significantly ($p<0.01$) different between the bulls in the first 22 weeks and thereafter the differences disappeared. The non-supplemented bulls recorded thicker scrotal skin as compared to the supplemented bulls. The mean scrotal skin thickness for both treatment groups increased steadily towards the end of the trial when the mean scrotal skin thickness of 0.6±0.0cm was recorded in both groups (not shown). The time x nutrition interaction effect recorded was also highly significant ($p<0.01$) on scrotal skin thickness, but the contribution of each factor is difficult to clarify.

Scrotal skin thickness was positively ($p<0.01$) correlated with scrotal circumference ($r = 0.5$), testis volume ($r=0.5$), testis length ($r = 0.4$), and body weight ($r = 0.5$). No significant effect of supplementation was observed during the course of the study period, indicating that either the supplementation level or the duration of the study was not adequate to induce subcutaneous fat accumulation in the scrotum.

Conclusion

In the current study, the supplemented bulls recorded higher ejaculate volume as compared to the non-supplemented bulls. Moreover, though not statistically significant, they tended to produce creamy semen colour, higher motile sperm and semen of higher concentration as compared to their contemporaries. Considerable variation was also observed between individual animals regarding the parameters measured. This may indicate the possibility to improve fertility in Horro bulls through selection.

Testicular measurements such as scrotal circumference, testis volume and scrotal skin thickness can be seen as the most useful measurements under farm conditions used to estimate the fertility of bulls. Thus, the current study could be regarded as an important source of primary information for further evaluation of Horro bulls' fertility. As the study was not exhaustive further study using animals of different age groups is warranted to get a complete picture of the impact of nutritional supplementation on semen quality and testicular measurements on Horro bulls. In addition the use of animals of different age groups, investigation of different feeding levels should also be considered to exploit the potential of this breed to the full.

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Eth. J. Anim. Prod. 6(1) - 2006: 33-53

Performance of the Abernosa Ranch in the Production of Ethiopian Boran X Holstein Crossbreed Dairy Heifers in Ethiopia*

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Abstract

The present study was conducted to evaluate reproductive performance of Ethiopian Boran cows at Abernosa ranch in the production of Boran x Holstein-Friesian F_1 crossbred dairy heifers for distribution to smallholder farmers. Performance data from the ranch between 1993 and 2001 was used for this study. The results show delayed age at first conception (53.9 months) and long calving interval (534.3 days), with average breeding efficiency of 44.6%, average calving rate of 72% and heifer production efficiency of only 38%. The pre- and post-weaning calf mortality rates were 17.3 and 2.9%, respectively. These led to a very low average cost recovery on in-calf heifer production of only 14.6%. Based on the average herd productivity parameters determined in this study, it was calculated that this rate of cost recovery could be improved three-fold to 42.8% by introducing such realistic management interventions as replacement of old and unproductive cows with average performing ones, enforcing a clearly defined breeding practice, managing open cows and heifers separately for better heat detection, supplementary feeding and timely mating, and full utilization of the available resources for the key output of the ranch – in-calf crossbred heifers. Furthermore, between 1994 and 2000, annually on average 20% of the crossbred heifers were culled for health difficulties, physical injury and unknown reasons. If this rather high culling rate could be reduced by half through separate and proper management of heifers, the number of available heifers for mating could be increased by 15.4%, and with this also the number of in-calf heifers available for distribution. Overall, it was noted that the production of in-calf crossbred heifers in the ranch has been very inefficient. It was therefore recommended that alternative ways of producing crossbred heifers such as contract production with smallholder farmers or commercial farmers and direct production of crossbred

* This paper is part of a thesis of the senior author (Ababu, 2002).

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heifers in the hands of smallholder farmers who own suitable indigenous cows should be considered for more economical production of crossbred heifers.

Keywords: crossbred heifers, production efficiency, Boran cattle, Abernosa ranch.

Introduction

Despite the widely held belief that crossbreeding of indigenous cows with improved exotic dairy-type breeds could lead to rapid and sustainable increases in milk production from smallholder dairy farmers (McDowell, 1972, 1988; Teferra and Abay, 1992), it is still debatable whether crossbreeding is economically worthwhile to smallholder farmers and sustainable in the low-input production environments in Ethiopia. Small herd sizes, rapid turn over of breeding stock and lack of controlled mating are known to constrain sustainability of crossbreeding interventions in smallholder settings (Workneh *et al.*, 2002). Furthermore, in countries like Ethiopia, there are difficulties of maintaining continuous supply of proven semen or breeding bulls (Mohammed, 2004; Ababu *et al.*, 2004).

Under the usually harsh tropical environments with limited feed supplies and heavy disease challenge, temperate cattle breeds cannot sustain adequate performance. Crossing up to levels of exotic blood of 75% are known to bring about improvements in almost all traits, but further grading towards the *Bos taurus* breed has given variable and often disappointing results (Cunningham and Syrstad, 1987). More attention should be given to raising productivity of the indigenous animal from low to intermediate rather than to promoting exotic genotypes for expected high productivity that cannot be supported economically by the production environment (McDowell, 1985). Genetic improvement of smallholder livestock through crossbreeding could have undesirable consequences when the matings are not controlled and the essential replacement are not supplied sustainably (Workneh *et al.*, 2002).

Higher levels of production than those achieved in traditional tropical systems often require the introduction of specialised dairy breeds and increased levels of inputs (nutrition and health care) and good linkages to markets, both for milk sales and input acquisition. Thus, the intensification of smallholder livestock systems through the adoption of improved dairy production is generally concentrated in areas with good infrastructure close to major markets, although less intensive production may occur in more

distant areas (Walshe *et al.*, 1991). These market factors, therefore, play a major part in determining the type of dairy production system that can succeed in the tropics, and they are particularly important influences on smallholder dairy development.

In smallholder livestock systems of Ethiopian highlands, bull and Artificial Insemination (AI) services are either weak or declining for various reasons, including lack of replacements for aging/castrated exotic bulls and weak and inconsistent AI services (Ababu *et al.*, 2004). Farmers may not have control over the genotype of the AI bull and may not use designated bulls. This implies that there is no room for controlling the build up of inbreeding, or for monitoring genetic change in smallholder herds. Usually, due to lack of grazing and feed resources, farmers in Ethiopian highlands give priorities to breeding females, replacement heifers and castrated oxen for traction, instead of maintaining breeding males. On the other hand, AI requires a good infrastructure such as a network of AI points, semen distribution, field inseminators and regular supply of liquid nitrogen. Dairy farmers must also have good skills in heat detection and keeping appropriate timing for AI services. These needs to be complemented by reliable and responsive system of AI service delivery.

The economic viability of dairy enterprises depends not only on milk production and good reproductive performance of dairy cows, but also on efficient production of heifers as well (Sodakar *et al.*, 1988). As part of dairy improvement programs, the livestock extension services in Ethiopia have relied on the production of in-calf heifers in government-owned cattle crossbreeding stations at Abernosa, Gobe, Metekel and Andasa ranches. Such a production of crossbred heifers involves heavy capital outlay in the form of ranch infrastructure, technical supervision, provision of health care, herding, fencing, feeds and pasture improvement. Delivery of crossbred heifers from these ranches has been handled through credit and direct sale through the agricultural extension services. The relative merit of producing crossbreds in such ranches vis-à-vis other alternatives is yet to be investigated. At least three alternative sources of crossbred heifers could be tried in Ethiopia. These are on-farm contract production with smallholder farmers who own the desired breed of indigenous cows, direct procurement from major dairy production areas, such as the Selale area, and contract production by commercial farmers. However, only ranch-based production of crossbred heifers has been promoted so far by the extension services, with

the selling price of heifers set not at the level of the ranches but centrally. Under these circumstances, it is logical to evaluate the performance of ranch production of crossbred heifers at one of these ranches – in this case Abernosa – with the view to quantifying heifer production efficiency, and, based on this, identify relevant intervention points for improving efficiency.

The Abernosa cattle breeding ranch was established in 1962 initially to undertake genetic improvement of the Boran cattle for beef production and that activity was discontinued in 1972 when a major decision was made to change the objective to the production of crossbred (Ethiopian Boran x Holstein Friesian) dairy heifers for distribution to smallholder farmers in the highlands through local agricultural extension offices with the objective of increasing milk production by the smallholder farmers in mid and highland areas of the country (Azage, 2004). The ranch is at present under the management of the Oromia Region Bureau of Agriculture and Rural Development (OBARD), which has a growing need for production of in-calf F_1 crossbred heifers. The F_1 heifers are distributed to farmers at highly subsidized prices, and yet the cost of producing heifers has not as yet been critically assessed. If this was known, then it would be possible to compare it with alternative ways of producing F_1 heifers. One such alternative is to produce them in the hands of farmers using the artificial insemination services, which however has not been exploited specifically for this purpose. It is not known whether the Abernosa ranch is operating at full capacity and whether it makes effective use of the breeding stock for production of F_1 crossbred heifers. This study was therefore conducted to: 1) evaluate the reproductive performance of Boran cows in the ranch and identify the influence of non-genetic factors on reproduction; and 2) assess heifer production efficiency in the ranch.

Materials and methods

The study area

The Abernosa ranch is located at 180 km south of Addis Ababa in East Shoa Zone of Oromia National Regional State, Ethiopia, on the road from Addis Ababa to Awassa. The ranch currently has a total area of 2548 ha that lies in the altitude range of 1500 to 1600 masl. The rainfall distribution is bimodal, but is erratic and unreliable. The main rainy season is from June to September while the short rainy season is between mid March and May. The dry season extends from October to mid March. The annual average rainfall is

700 mm, with average temperatures of 21^0C. The vegetation is mostly composed of perennial grasses with sparsely populated Acacia trees.

Herd management and breeding program

The ranch follows a calf-cow program in which calves are allowed to suckle their dam from birth up to weaning. Herds are managed separately depending on their age, stage of pregnancy, breed and sex. Matings are mainly meant to produce F_1 crossbred heifers whereby the dam and sire lines are the Boran and the Holstein-Friesian, respectively. Holstein Friesian semen obtained from the National Artificial Insemination Center (NAIC) at Kaliti is used to breed both Boran cows and their F_1 crossbred heifers. Herdsmen are responsible for heat detection. The mating date and sire identification number are recorded for every insemination and transferred to individual cow record cards, which also contains data on parturition, abortion and health records. Mating is allowed throughout the year.

Reproduction data made available in individual cow record cards for the period 1992 to 2001 was collected and used for this study.

Statistical analysis

Least squares analysis of the GLM procedure of SAS (1999) to analyse reproductive parameters. Mortality was handled as a response and analysed in the same way where season and year of birth, parity and sex of calf were considered as fixed effects. The response variables were Age at First Calving (AFC), Number of Services per Conception (NSC), Days Open (DO), Calving Interval (CI), Calving rate (CR) and Breeding Efficiency (BE). CR was taken to men the number of calves born per 100 inseminations. Breeding efficiency (BE) was taken as a measure of the number and regularity of calvings in a cows reproductive life, i.e. Breeding efficiency = (365 x (N-1) x 100)/D; where, N = total number of parturitions, and D = days from first to last parturition (Wilcox, 1957). The following general statistical model was used in data analysis:

$$Y_{ijklm} = \mu + R_i + S_j + P_k + X_l + e_{ijklm}$$

Where, Y_{ijklm} related to the various traits, including AFC, NSC, DO, CI, CR and BE.

μ is the overall mean

R_i is the effect of calving year (i = 1992, …. 2000)

S_J is the effect of calving season (j=main rainy, dry, short rainy)

P_k is the effect of parity (k= 1, 2, 3, 4, 5, 6)

X_l is the effect of sex (l= female, male), and

e_{ijklm} is the random error

Yearly heifer production efficiency was determined by relating the total female calves born with those available for mating and confirmed pregnancy in these heifers. These are then compared with total numbers of heifers distributed per year. Sale value, cull value and annual operation cost including labor cost (salary) were considered. Heifer production was taken to mean all female crossbreds born, less those that died and were culled. Cull value included sale of all culled animals.

Results and Discussion

Bearing Ability

Age at first calving (AFC)

The overall average age at first calving for Boran heifers mated using artificial insemination during the study period was 53.9±0.70 months with coefficient of variation of 8.17% (Table 1). Entry year, season, and age at arrival at the ranch had highly significantly ($p < 0.001$) effected on AFC. The wide variation in AFC between years can be explained by changes in the level of management (e.g. feed supply) and varying effectiveness of heat detection and scarcity of feeds at the ranch over the years. Varying numbers of heifers were introduced into the ranch from 1996 and their ages were variable with overall mean of 29 months.

Heifers which first entered during the short rainy season generally tend to calf at younger age than those which entered during dry and rainy seasons. This can be explained by the differences in the ages of heifers brought into the ranch, which also relates to the increasing trend of average AFC over the entry years from 1996 to 2000.

The estimated average age at first calving for this breeding population is comparable with the observations made by Kumar and Bhat (1979) for Hariana cattle in India, by Wagenaar *et al.* (1986) for Fulani cattle in Mali, by Saeed *et al.* (1987) for Kenena cattle at Um Banein, the Sudan and by Mukasa-Mugerwa *et al.* (1989) for indigenous cattle in central Ethiopia.

Number of services per conception (NSC)

The average number of services per conception for 1513 service records was 1.5 ± 0.06 with coefficient of variation of 29.2% (Table 2). This average is lower

than values reported for Fogera cattle and their crosses in Gondar (Mekonnen and Goshu, 1987), but higher than values reported for Boran cattle in Abernosa ranch (Mekonnen, 1987), other Ethiopian indigenous zebu cattle and their crosses with temperate breeds at Holetta (Azage, 1981), Arsi zebu and their crosses in Arsi at Asela (Swensson *et al.* 1981) as well as those of the same herd about a decade later (Enyew, 1992).

Table 1. Least square means for Age at First Calving (AFC) (months) by entry season, entry year and entry age

Variables	No	Mean±SE (CV =8.17%.)
Overall	344	53.93±0.70
Entry season		***
Main rainy	117	53.77^{ab}±0.79
Dry	109	56.16^{a}±0.79
Short rainy	118	51.86^{b}±0.76
Entry year		***
1996	4‡	47.20^{c}±2.20
1997	162	48.15^{c}±0.39
1998	31	56.20^{b}±0.79
1999	111	53.23^{b}±0.50
2000	34	62.75^{a}±0.81
2001	2	62.07^{b}±3.11
Entry age§		***
<20 months	29	50.05^{b}±1.05
20-30 months	168	51.20^{b}±0.69
>=30 months	147	60.55^{a}±0.73

*** = P < 0.001; Means within variable followed by the same superscript do not differ significantly at *P* = 0.05. SE= Standard Error; CV = Coefficient of variation.

Mating year showed a highly significant (P < 0.001) effect on NSC whereas mating season and parity had no significant effect. Over the study period, NSC gradually increased over the years, which is strongly related to efficiency of inseminators (McDowell, 1972). Besides NSC is influenced by the level of nutrition and hence body condition of mating cows. NSC was not affected by parity.

‡ Too low numbers of animals in the years 1996 and 2001 are noted; these are retained in tables to better reflect trends, and hence should be interpreted with caution.

§ Entry age data was based on estimated ages of the heifers at purchase.

Table 2. Least square means for number of services per conception (NSC) by mating season, mating year and parity.

Variables	No	Mean ± SE (C V= 29.21%)
Overall	1513	1.50±0.06
Mating season		NS
Main rainy	598	1.59±0.07
Dry	600	1.48±0.07
Short rainy	315	1.45±0.08
Mating year		***
1992	33	1.00^{e}±0.30
1993	115	1.19^{de}±0.12
1994	63	1.32^{cde}±0.15
1995	195	1.30^{cde}±0.09
1996	165	1.42^{cd}±0.10
1997	303	1.60^{bc}±0.08
1998	165	1.86^{ab}±0.09
1999	312	1.99^{a}±0.07
2000	162	1.88^{ab}±0.09
Parity		NS
1	573	1.47±0.05
2	403	1.61±0.07
3	262	1.46±0.08
4	164	1.60±0.09
5	90	1.58±0.12
6	21	1.32±0.25

*** = P < 0.001; NS = Non-significant; Within variable, means followed by the same letter do not differ Significantly at *P* = 0.05. SE= Standard Error; CV = Coefficient of variation.

Days open (DO)

The overall least square mean for DO was 305.9 ± 17.77 days with a coefficient of variation of 48.4% (Table 3). Analysis of variance of the trait showed that calving year and parity had very highly significant ($p < 0.001$) effect and calving season within calving year had highly significant ($p < 0.01$) effect on this variable. Cows that calved in 1993 and 1998 showed the highest DO (384.28 ± 30.56 and 384.66 ± 20.46 days), while the lowest DO was observed in 2000.

Cows that calved during the main rainy season had the shortest average DO, followed by those that calved during the dry period. Seasons reflect availability of green fodder, which determine body condition of the postpartum cows. Shorter DO in the subsequent dry season than during the short rainy season appears to be related to mortality of calves during the dry period, which allowed cows to come into heat earlier. During the study period pre-weaning mortality of calves during dry season was as high as 17%. It was also observed in this study that cows than calved during the

short rainy season tended to have longer DO, apparently due to the longer time it took postpartum cows to recuperate during the subsequent dry period. In a herd using AI, DO is heavily dependent on the efficiency and timing of heat detection. Suckling is also known to affect DO (Eduvie and Dawuda, 1986).

Calving interval (CI)

The overall least square mean for CI was 534.3 ± 17.64 days with a coefficient of variation of 24.3% (Table 3), which is longer by about three months of the ideal interval of 15 months. Year of calving and parity affected ($P < 0.001$) CI. The effect of calving season within calving year on CI was also highly significant ($P < 0.01$).

In the present study, shorter CI was observed for cows that calved during the main rainy season which could be attributed to availability of adequate pasture around the calving period and during the early postpartum (main rains) as well as during the previous short rainy season (late gestation). Supplemental feeding for lactating cows during the dry season can significantly shorten CI; for instance, Weitze (1984) reported that CI was reduced through supplementary feeding by 52 days with calving rate of 83% in Nellore, Gir and InduBrazil cattle in Brazil.

Prior to purchase and arrival at the ranch, the Boran heifers were reared under traditional pastoral management, which does not necessarily provide the minimum nutritional requirements of their early growing period. These poorly developed first calf heifers could have longer CI. Younger cows have higher nutrient requirements for growth as well as milk production, and hence low plane of nutrition leads to longer CI and DO. Similarly, effect of season tends to have more pronounced effect on the first than subsequent calving intervals (Oyedipe *et al.*, 1982). Medium aged cows gain body condition quickly after calving, leading to shorter CI subsequently. Young, old and weak cows often take longer time to recover from the past parturition and lactation stress.

Calving rate (CR)

The overall least squares mean CR of 870 insemination records was 71.9% ± 1.99, a with coefficient variation of 22.5% (Table 3). CR was significantly ($p < 0.001$) affected by parity and season of calving within calving year ($p < 0.01$). The highest CR was observed in 2000 and the least was in 1998. The difference in calving rate between years could be attributed to variation in

level of management between the years. Similar observations reported on Angoni cattle in Zambia (Thorpe *et al.*, 1981) and zebu cattle in Panama (Espaillat *et al.,* 1979) relate these to poor feeding and heat detection efficiency.

Table 3. Least square means for Days Open (DO), Calving Interval (CI) and Calving Rate (CR) by calving season, year and parity.

Variables	Days Open (CV= 48.46%)		Calving Interval (CV= 24.35%)		Calving Rate (CV= 22.55%)	
	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE
Overall	793	305.9±17.77	870	534.33±17.64	870	71.87±1.99
Calving season within year		**		**		NS
Main rainy	223	302.90^{c}±19.70	245	532.39b	245	71.83±2.20
Dry	334	306.50^{b}±18.50	356	538.28a	356	70.99±2.07
Short rainy	236	308.19^{a}±19.36	269	532.33b	269	72.76±2.15
Calving year		***		***		***
1993	34	384.28^{a}±30.56	44	589.74a±28.39	44	66.67c±3.21
1994	99	306.50^{b}±23.49	113	532.61^{b}±22.86	113	70.89^{c}±2.59
1995	89	263.35^{cd}±23.58	87	498.20^{c}±23.64	87	76.36^{b}±2.68
1996	129	280.83^{cd}±22.34	135	523.27^{c}±22.09	135	72.72^{b}±2.50
1997	147	297.48^{cd}±21.39	151	530.55^{c}±21.31	151	79.79^{b}±2.41
1998	187	384.66^{a}±20.46	223	612.56^{a}±20.13	223	63.10^{c}±2.28
1999	83	322.04^{bc}±22.95	90	559.30^{bc}±22.53	90	66.95^{c}±2.55
2000	25	207.77^{d}±28.36	27	428.44^{d}±28.49	27	85.43^{a}±3.22
Parity		***		***		***
1	328	311.72^{a}±8.99		585.99^{a}±8.71	373	66.85^{b}±0.99
2	216	254.83^{c}±11.18	373	529.79^{b}±10.78	228	72.92^{a}±1.22
3	145	237.81^{c}±13.79	228	516.93^{b}±13.45	151	74.16^{a}±1.52
4	84	220.64^{c}±16.40	151	495.69^{b}±15.82	93	77.08^{a}±1.79
5	20	239.09^{ab}±31.71	93	500.19^{b}±29.94	23	76.32^{a}±3.39
6			23	577.42^{ab}±100.15	2	63.86^{ab}±11.35

*** =P<0.001; ** =P< 0.01; Within variable, means followed by the same letter do not differ significantly at P = 0.05. SE= Standard Error; CV = Coefficient of variation.

Rearing Ability

Birth weight (BW)

The overall least squares mean BW of 1407 Boran x Holstein-Friesian F_1 crossbred calves was 24.4± 0.14 kg with a coefficient of variation of 10.6% (Table 4). Calving season, calving year and parity showed significant ($p < 0.001$) effect on BW. The heaviest BW was observed in 1996 and the lowest was in 1999. These variations are closely related to changes in feed availability as well as overall management over the years, for instance due to the political instability in 1993 and 1994 and the changing management policies since then.

Calves born during the main rainy season were heavier than those born in the other two seasons, which could be explained by the relatively better plane of nutrition to cows in their late stages of gestation. Better feed availability during the last phase of pregnancy helps faetal growth and hence greater weight of calves at birth.

The observed average BW for these F_1 crossbred calves are less than similar values reported for Arsi x Holstein-Friesian calves in Arsi (Kiwuwa *et al.*, 1983), Boran x Holstein-Friesian calves in Abernosa (Mekonnen, 1987), and Fogera x Friesian calves in Metekel (Addisu, 1999). A possible explanation for this the generally lower level of management than in the other ranches.

Weaning weight (WW)

The overall least squares mean WW of 905 Boran x Holstein Friesian crossbred calves at weaning age of 8 months[**] was 140.7 ± 2.62 kg with a coefficient of variation of 18.4% (Table 4). Calving season and calving year had significant ($p < 0.001$) effect on WW. The highest weaning weight was recorded in 1997 and the lowest in 1999. Calves born during the dry season had higher weaning weight than those calves born during main and short rainy seasons, which had almost similar weaning weights. The lower WW of calves born during short rainy season may be attributed to poor nutrition of the dams during the last phase of pregnancy, which affects foetal development, and poor postpartum milk yield of dams. As stated earlier, the dry season is associated with the lowest BW weight; however, the better feed supplied to suckling cows during the subsequent main rainy season led to higher WW of those calves born in dry season. As reported in the related larger study (Ababu, 2002), the total body weight gain and average daily weight gain from birth to weaning of the study animals in the ranch were found to be 116.4 kg and 484 gm, respectively.

Pre-weaning mortality

The overall mean pre-weaning mortality rate was 17.3% (Table 5), and was significantly affected by parity ($p < 0.001$) and year of birth ($p < 0.01$). Production of crossbred heifers being the primary objective of the ranch, such high level of calf mortality considerably limits heifer production performance of the ranch. Blood *et al.*, (1989) estimated that a pre-weaning calf mortality of 20% can reduce net profit of dairy farms by 38%. Therefore, every possible

[**] Linear interpolation was used to estimate weaning weight at 8 months of age for records of weaning age below or above this target age.

effort should be exerted to minimize calf losses through mortality. Although calf mortality may be mainly attributed to diseases, it is often related to management problems (e.g. feeding, health care). Ibeawuchi *et al.* (1983) observed calf losses of 29.3% in Nigerian dairy herds, 61% of which occurred within the first 3-months of age and another 16% occurred in the second half of the six month of age. Young calves are more vulnerable to both infectious and non-infectious diseases that could result in mortality. The very high pre-weaning mortality of calves on first parity can be explained by the lower mothering ability of these cows compared to older cows.

Table 4. Least square means for birth weight and weaning weight by calving season, year, parity and sex of calf.

Variables	Birth weight		Weaning weight	
	No	Mean ± SE (CV = 10.6%)	No	Mean ± SE (CV = 18.4%)
Overall	1407	24.36±0.14	905	140.72±2.62
Calving season		***		***
Main rainy	505	24.94^{a}±0.17	305	139.68^{b}±2.97
Dry	524	24.10^{b}±0.16	357	143.03^{a}±2.81
short rainy	378	24.05^{b}±0.18	243	139.47^{b}±2.99
Calving year		***		***
1993	42	23.89^{d}±0.44	24	127.92^{bc}±5.77
1994	99	24.22^{bcd}±0.30	69	131.63^{bc}±3.68
1995	82	24.30^{bcd}±0.33	58	149.91^{ab}±3.95
1996	160	25.32^{a}±0.25	119	140.11^{abc}±3.02
1997	166	24.42^{ab}±0.24	140	157.82^{a}±2.85
1998	319	25.23^{a}±0.19	264	139.80^{abc}±2.23
1999	156	23.74^{cd}±0.23	112	118.32^{c}±2.79
2000	258	24.48^{abc}±0.19	117	150.55^{ab}±2.65
2001	125	23.67^{bcd}±0.25	2	150.51^{ab}±18.58
Parity		***		NS
1	537	24.04^{a}±0.12	348	137.70±2.59
2	368	24.53^{a}±0.15	232	141.08±2.85
3	236	24.94^{a}±0.20	155	145.60±3.16
4	157	25.09^{a}±0.23	112	146.74±3.43
5	89	24.84^{a}±0.29	46	136.05±4.34
6	20	22.73^{b}±0.60	12	137.21±8.01
Sex		NS		NS
F	728	24.33±0.15	479	140.57±2.75
M	679	24.39±0.16	426	140.88±2.80

*** = P < 0.001; Within variable, means followed by the same letter do not differ significantly at *P* = 0.05; SE= Standard Error; CV = Coefficient of variation.

Post-weaning calf mortality

The overall least squares mean post-weaning mortality rate was 2.9% (Table 5). Parity, year of birth and season of birth showed highly significant

($p < 0.001$) and significant ($p < 0.01$) effect on post-weaning mortality. Post-weaning mortality did not vary between sex of calves. Higher post-weaning mortality rates were observed among calves born during the dry and short rainy seasons. This can be explained by the fact that weaned calves had to pass through stressful pre-weaning conditions that predispose them to disease conditions. As a result these animals tend to have less capacity to withstand post-weaning changes in feed, grazing and housing.

Table 5. Pre- and post-weaning mortality of F_1 crossbred calves

Variables		Pre-weaning mortality		Post-weaning mortality	
		N	Mean ± SE	N	Mean ± SE
Overall		174	17.3±1.10	61	2.9±0.29
Season of birth			NS		**
	Main rainy	51	16.6±1.69	22	2.0^{b}±0.42
	Dry	80	17.0±1.38	21	3.3^{a}±0.39
	Short rainy	43	18.4±1.77	18	3.6^{a}±0.45
Year of birth			**		***
	1994	2	7.9^{cd}±3.2	_	
	1995	11	23.6^{a}±3.27	3	7.2^{a}±0.77
	1996	16	20.1^{ab}±2.44	7	3.3^{cb}±0.63
	1997	21	19.9^{ab}±2.36	7	3.2^{cb}±0.59
	1998	47	18.1^{ab}±1.73	9	2.9^{b}±0.45
	1999	26	17.0^{ab}±2.31	25	1.7^{cbd}±0.82
	2000	51	14.8^{bc}±1.95	10	1.8^{cd}±0.78
Parity			***		***
	1	87	22.2^{a}±1.43	22	3.0^{a}±0.39
	2	28	9.7^{ab}±1.67	8	1.4^{b}±0.45
	3	18	11.9^{ab}±2.20	14	2.7^{b}±0.57
	4	28	25.2^{a}±2.33	14	5.5^{a}±0.65
	5	13	17.7^{a}±3.41	3	2.0^{b}±1.03
Sex			NS		NS
	F	91	17.4±1.35	32	2.9±0.35
	M	83	17.3±1.37	29	2.9±0.38

*** = P < 0.001; ** = P < 0.01; NS = Non-significant; Within variable means followed by the same letter do not differ significantly at $P = 0.05$.

Cow Production Efficiency

Breeding efficiency (BE)

The overall least squares mean BE of 675 calving records was 44.6 ± 0.57% (Table 6). Calving season, year and parity had significant ($P < 0.001$) effect on BE. Average BE substantially declined from 1996 to 2000. The significant seasonal effect indicates that the breeding efficiency was higher among cows bred in the dry season than those bred in the short and long rainy seasons. Cows that calved during the dry season can take advantage of better feed supplies of the subsequent rainy season to start cycling soon. BE was also

higher among the third and fourth parity than the first and second parity groups (Table 6).

Kiwuwa *et al.* (1983), in their study at Asela farm, estimated average BE of 64% and 68% for the indigenous Zebu and Arsi cattle, respectively, and reported that BE was significantly affected by season, year and parity.

Table 6. Least square means for breeding efficiency by calving season, year and parity.

Variables	N	Mean ± SE
Overall	675	44.61±0.57
Calving season		***
Main rainy	266	43.62^{b}±0.59
Dry	240	45.24^{a}±0.61
Short rainy	169	44.96^{a}±0.60
Calving year		***
1996	12††	56.16^{a}±1.14
1997	166	45.45^{b}±0.61
1998	65	42.73^{c}±0.68
1999	264	40.59^{d}±0.57
2000	168	38.09^{e}±0.54
Parity		***
1	424	36.06^{c}±0.25
2	194	29.50^{d}±0.34
3	54	48.65^{b}±0.56
4	3	64.21^{a}±2.02

*** = P < 0.001; Within variable means followed by the same letter do not differ significantly at P = 0.05.
CV = 10.67%.

Heifers production efficiency

During the study period, on average only 65% of the female calves born reached puberty; the average efficiency of getting heifers in-calf to the third month of pregnancy was only 61.4 %. Out of the in-calf heifers, only 95% could be distributed. Overall about 38% of the female calves born could be distributed as in-calf heifers to smallholder farmers (Table 7). The rest had been lost to mortality, culling and unexplained losses.

Comparison of operation cost with the value from sale of crossbred heifers and culled animal showed that crossbred heifer production was at low level of cost recovery. In the present study the projected heifer production efficiency is 42.8% taking into account the actual number of cows, their calving rate and observed calf viability (Table 9). This index assumes that cows of average fertility are maintained in the ranch are these are fully

†† Because of the too small size of samples for year 1996 and fourth parity are retained to better show trends, but the results should be interpreted with caution.

utilized for crossbred heifer production and this is nearly triple of the observed heifer production and the sale of only 14.6% between 1994 and 2000 (Table 8). During the seven year period only 269 heifers were dirstributed. This wide gap between the actual and projected efficiency indicates the large opportunity for improving performance of the ranch.

Late age at first calving, prolonged days open, long calving interval and high mortality were responsible for the low returns. High mortality (106) and high rate of culling of females (141) substantially reduced the number of heifers available for distribution (Table 8). If this rather high culling rate could be reduced only by half (to 71) through separate and proper management of heifers, the number of available heifers for mating could be increased from 461 to 532, i.e. an improvement of 15.4%. This improvement would also increase the number of in-calf heifers available for distribution, and hence heifer production efficiency.

Conclusions

Overall performance of the Abernosa ranch in s in the production of Ethiopian Boran x Holstein crossbreed dairy heifers 1992 and 2000 was very low. The overall total heifer production efficiency during the observation period was only 38%. Only 65.1% of the female calves reached mating. Delayed AFC, too long DO and long CI were observed. Calving rate and breeding efficiency were low, as can be expected from the long period of CI. Pre-weaning mortality was also high (17.3%). Consequently the average number of viable heifers produced per cow was low. There have been significant effects of environmental factors (season, year, parity and sex) on overall performance. As a result not only that overall reproductive performance was inadequate, but also the fluctuations in performance limit the scope for identifying key limiting factors and designing appropriate interventions.

Table 7. Annual heifer production efficiency between 1994 and 2000

Birth year	Total females calves born (a)	Total heifers available for mating (b)	Heifer growing efficiency (%) (c=b/a)	Confirmed pregnancy (d)	% confirmed pregnancy (e=d/b)	Total in-calf heifers distributed (sold) (f)	Heifer distribution efficiency (%) (f/d)	Total heifer production efficiency (%) (f/a)
1994	58	24	41.4	NA	NA	6	-	10.3
1995	58	33	56.9	22	66.7	20	90.9	34.5
1996	89	67	75.3	52	77.6	50	96.2	56.2
1997	79	52	65.8	23	44.2	18	78.3	22.8
1998	179	134	74.9	72	53.73	68	94.4	38
1999	89	40	44.9	40	100	35	87.5	39.3
2000	156	111	71.2	74	66.7	72	97.3	46.2
Total	708	461	65.1	283	61.4	269	95	38

NA= Not available

Table 8. Observed Cost recovery of heifer production (based on total females born, died and culled) (title needs to be revised)

Year	Total female calves born	Total females calves died	Heifers culled	Heifers ready for mating	Income from sale of in-calf heifers (@Birr1200) (H)	Income from sale of culled animals (I)	Total operation costs (J)	Net cost of in-calf heifers production (O= J-I)	Cost recovery of in-calf heifer production (H/O*100)
1994	58	3	31	24	7200	17653.00	293597	275944	2.6
1995	58	11	14	33	24000	54005.25	400301	346296	6.9
1996	89	11	11	67	60000	12237.05	324433	312196	19.2
1997	79	15	12	52	21600	27065.77	276691	249626	8.6
1998	179	27	18	134	81600	59002.65	364176	305174	26.7
1999	89	19	30	40	42000	109462.40	475399	365937	11.5
2000	156	20	25	111	86400	81663.65	436623	354960	24.3
Total	708	106	141	461	322800	361089.77		2210134	14.6

Table 9. Projected heifer production efficiency based on the number of cows available for reproduction, observed calving rate and viability before and after weaning.

Year	No. cows (a)	Calving rate (b)	Viability before weaning (c)	Viability after weaning (d)	F:M Ratio (e)	Heifers produced (f= a*b*c*d*e)	Culled (unfit) Heifers (g)	Income from sale of heifers (h = 1200/heifer)	Income from culled heifers (i)	Estimated labour cost (salary and wages) (j)	Recurrent cost (k)	Total operation cost (l= j+k)	Net cost of heifers production (m= l-i))	Rate of cost recovery of heifer production (h/m*100)
1994	404	0.67	0.92	0.99	0.5	123	31	110400	17653	151212	142385	293597	275944	40.0
1995	328	0.71	0.76	0.92	0.5	81	14	80400	54005	160596	239705	400301	346296	23.2
1996	342	0.79	0.79	0.96	0.5	102	11	109200	12237	152100	172333	324433	312196	35.0
1997	592	0.74	0.80	0.96	0.5	168	12	187200	27065	152100	124591	276691	249626	75.0
1998	546	0.74	0.81	0.97	0.5	158	18	168000	59002	172260	191916	364176	305174.	55.0
1999	687	0.64	0.82	0.98	0.5	176	30	175200	109462	208908	266491	475399	365937	47.9
2000	569	0.65	0.85	0.78	0.5	122	25	116400	81663	213072	223551	436623	354960	32.8
Total							141	946800					2210134	42.8

Comparison of the value from sale of crossbred heifers and culled animals against cost of operation at the ranch showed that crossbred heifer production in the ranch was highly subsidized. Projected heifers production efficiency using the current stock of cows alone at the observed rate of reproduction and removing unproductive cows indicated that heifer production in the ranch could be tripled from the current rate of 14.6% to 42.8%.

Recommendations

In view of the very inefficient production of in-calf crossbred heifers in the ranch, three alternative ways of producing crossbred heifers are recommended: 1) direct production of crossbred heifers in the hands of smallholder farmers who own suitable indigenous cows and can get effective AI services; 2) contract production of crossbred heifers with smallholder dairy farmers; and 3) contract production of crossbred heifers in commercial dairy farms with capacity to maintain indigenous cows.

If the ranch is to continue with producing the crossbred heifers, AFC, DO, and CI should be improved through improvements of overall management, particularly heat detection and timely insemination. The high calf mortality rates should be reduced by good sanitation, health care and proper feeding of lactating cows and their calves. There should also be a sound and consistent culling policy. The current practice of purchasing largely unknown Boran heifers reared under traditional pastoral management does not allow selection of good breeding heifers. An alternative to this is to produce replacement heifers in the ranch, which would also allow initiation of genetic selection.

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Herd Life and Lifetime Calf Crop Production in Relation to Age at First Calving in Indigenous and Crossbred Cows at Bako, Ethiopia

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Abstract

A study was conducted to determine longevity, productive and unproductive lifetime and lifetime calf crop production of Horro, Boran and their F_1 crosses with Friesian, Jersey and Simmental using data collected at Bako Agricultural Research Centre. The data was analyzed using the general linear model of the statistical analysis system. Accordingly the result indicated that cow breed significantly affected lifetime calf crop production ($P < 0.01$), longevity ($P < 0.05$), productive ($P<0.05$) and unproductive lifetime ($P < 0.01$) of the cows. Horro cows had significantly ($P < 0.05$) the highest lifetime calf crop (5.2 ± 0.24 calves) while the Horro x Friesian, Boran, Boran x Friesian, Boran x Jersey and Boran x Simmental cows had significantly ($P < 0.05$) the lowest lifetime calf crop. Besides, the highest longevity and productive lifetime were recorded for pure Horro and Horro x Jersey crosses compared to the other genotypes considered in this study. Moreover, the unproductive lifetime (age at first calving) was longest for Boran cows followed by Horro cows and the lowest unproductive lifetime was recorded for the crossbred cows. The relationship of age at first calving with lifetime calf crop production ($b = -0.56 \pm 3.89$; $P < 0.001$), longevity ($b = 0.57 \pm 2.74$; $P < 0.01$) and productive lifetime ($b = -0.435 \pm 2.11$; $P < 0.05$) of the cows was linear and significant. It was also significantly correlated with longevity ($r = 0.24$; $P < 0.001$), productive life ($r = -0.13$; $P < 0.05$) and lifetime calf crop production ($r= -0.22$; $P < 0.001$). Survival estimates calculated as proportion of cows that had their first calf (228 cows) survived and calved their 2nd, 3rd, 4th, 5th, 6th, 7th and 8th calf were 90.4, 80.3, 65.8, 46.5, 31.1, 10.5 and 5.7 %. From this study it can be concluded that cow breed and age at first calving affected lifetime traits.

Keywords: Longevity, lifetime, herd life, calf crop, zebu, crossbred, Bako

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Introduction

Longer lifetime and high lifetime production are the basis for a profitable dairy enterprise. Long herd life substantially decreases replacement cost per lactation and enables a cow to achieve its maximum capacity of performance when attaining full maturity (Hoque and Hodges, 1980; Hocking *et al.*, 1988; Essel, 1998). The potential for a long herd life depends on good health and fertility. It reduces treatment costs and the incidence of involuntary culling, which increase the scope for voluntary culling (Enyew *et al.*, 2000). Herd life of a cow is considered to be a trait of major economic value and has high heritability ranging to 0.69 (Basu *et al.*, 1983). Genetic and phenotypic correlations of herd life and productive life time were higher with first lactation milk yield (Chauhan and Hayes, 1993), indicating that the trait could be improved through improvement of the genetic makeup of the breed.

Herd profitability is affected whenever the culling policy is changed. Herd life is an interaction between dairy cow's merit and dairyman culling decisions and thus the length of cows herd life is an overall measure of the commercial merit of a cow (Robertson and Baker, 1966). In general, longevity has been measured by characteristics such as age at last calving, number of lactations initiated or completed, length from first calving to disposal, age at disposal and survival to various ages. In Ethiopia, different indigenous breeds and crossbreds were evaluated for growth (body weight and body weight gain at different ages), reproductive (age and weight at first calving, calving interval, postpartum anoestrus interval, fertility, etc.) and productive (milk yield and lactation length) performances (Albero, 1983; Sendros *et al.*, 1987a, 1987b; Chernet *et al.*, 2000) and most of the studies reported the superiority of the crossbreds (F_1) over the indigenous breeds in some of economically important traits. However, limited effort has been made to assess the lifetime traits of both indigenous and crossbred genotypes (Enyew et al., 2000; Gidey, 2001). The objective of this study is therefore to estimate the herd life and lifetime calf crop production performance of indigenous and crossbred cows and the effect of age at first calving on these lifetime traits.

Materials and Methods

Description of the study area: The study was based on data collected from 1980 to 2001 at the Bako Agricultural Research Centre. The centre is located 250 km west of Addis Ababa at an altitude of 1650 masl. The centre

received mean annual rainfall of 1200 mm in a bimodal distribution, 80% of which falls from May to September. The area has a mean relative humidity of 59% and mean minimum and maximum temperatures of 13.5 and 27 ^{o}C, respectively. Dominant grasses species include Hyperhenia and Sporobolus.

Animals and herd management: Pure Boran and Horro and their F_1 crosses with Jersey, Friesian and Simmental exotic sire breeds born in the centre were considered for the study. The feeding system during pre- and post-weaning periods of calves, heifers and cows of all breeds were similar. The calf feeding and management systems in centre were the same for all calves. The calves were bucket fed colostrums for five days and about 237 litres of whole milk per head for 98 days then weaned. The daily ration was divided into two and offered twice daily (morning and evening). Concentrate and hay were also offered during the daytime. The concentrate mixture included maize (49%), Noug seed cake (49%), bone and blood meal (1%) and salt (1%) while the hay was mainly Rhodes grass (*Chloris gayana*). Calves had free access to water. They were kept indoor until the age of six months except a few hours of exercise in nearby paddocks. After six months of age, all calves were let in a group to graze natural pasture (8 am to 5 pm). Supplementation with hay (Rhodes grass and natural pasture) or silage (Rhodes grass and maize silage) at night was practiced depending on the availability of hay and silage and the condition of the grazing paddocks. Concentrate supplement was restricted to calves, milking cows and pregnant cows mainly during the last trimester of pregnancy. All animals were routinely monitored for any health problem and annually vaccinated against Black Quarter, Anthrax, Contagious Bovine Plureo Pneumonia (CBPP) and Foot and Mouth Disease; drenched against internal parasites and sprayed against external parasites depending on the degree of infestation by ticks, respectively. The heifer breeding policy in the centre considers age and body weight and heifers are said to be ready for breeding when they are two years of age and attained a body weight of 200 kg and above. Heat detection was done visually (6-8 am and 5-6 pm) by a trained inseminator and throughout the grazing time by the herdsmen. Both local and crossbred cows and heifers observed in heat were bred either naturally (local or crossbred bull) or inseminated with Friesian, Jersey or Simmental semen to get calves with different exotic blood level for experimental purposes. Right after calving, the calf was separated from its dam and bucket fed colostrum and whole milk. The cows were hand milked twice (morning and evening). Postpartum

breeding resumes after 45 days of voluntary waiting period. The culling was based on health problem, old age and reproductive failure. In the centre, all cows were hand milked in the morning and evening.

Traits studied: The traits considered in this study are productive and unproductive herd lifetime, longevity and lifetime calf crop production. Herd life is measured as productive herd life (period from first calving to date of disposal), longevity (age of the cow at disposal), unproductive life (age at first calving) and lifetime calf crop production (total number of calves born during the life of the cow or total number of lactations initiated during the lifetime of the animal) (Arthur et al., 1993; Enyew et al., 2000).

Data and statistical analysis: The traits were analyzed using the General Linear Model and Correlation procedures of the Statistical Analysis System (SAS, 1999). In the analysis, cow breed was considered as fixed effect and age at first calving as a covariate. Eight cow breeds or genotypes (pure Boran, Boran x Jersey, Horro x Jersey, Boran x Simmental, Horro x Simmental, Boran x Friesian, Horro x Friesian and pure Horro) were considered. Besides, correlation coefficients were calculated for the correlation of age at first calving with the lifetime traits. Frequency analysis was also done to estimate the proportion of cows that had their first calf (228 cows) that survived and calved their 2^{nd}, 3^{rd}, 4^{th}, 5^{th}, 6^{th}, 7^{th} and 8^{th} calf.

Results

The overall mean lifetime calf crop production, longevity, productive and unproductive lifetime of the cows were 4.4 ± 0.01 calves, and 10.1 ± 0.01, 6.2 ± 0.01 and 3.9 ± 0.04 years, respectively (Table 2). Cow breed/genotype significantly affected lifetime calf crop production ($P < 0.01$), longevity ($P < 0.05$), productive lifetime ($P < 0.05$) and unproductive lifetime ($P < 0.01$) of the cows (Table 1). Horro cows had significantly ($P < 0.05$) the highest lifetime calf crop (5.2 ± 0.24 calves) while the Horro x Friesian, Boran, Boran x Friesian, Boran x Jersey and Boran x Simmental cows had significantly ($P < 0.05$) the lowest lifetime calf crop. Besides, the highest longevity and productive lifetime were recorded for pure Horro and Horro x Jersey crosses compared to the other genotypes considered in this study. Moreover, the unproductive lifetime (age at first calving) was longest for pure Boran followed by pure Horro cows and the lowest unproductive lifetime was recorded for the crossbred cows (Table 2).

The relationship of age at first calving with lifetime calf crop production ($b = -0.56 \pm 3.89$; $P < 0.001$), longevity ($b = 0.57 \pm 2.74$; $P < 0.01$) and productive

lifetime (b = -0.435 ± 2.11; P < 0.05) of the cows was linear and significant. Calf crop yield increased and productive lifetime prolonged at a rate of 0.56 and 0.44, respectively while longevity shortened at a rate of 0.57 for one-year reduction in age at first calving (Table 2).

Age at first calving was significantly correlated with longevity (r = 0.24; P < 0.001), productive life (r = -0.13; P < 0.05) and lifetime calf crop production (r = -0.22; P < 0.001). Survival estimates calculated as proportion of cows that had their first calf (228 cows) that survived and calved their 2nd, 3rd, 4th, 5th, 6th, 7th and 8th calf were 90.4, 80.3, 65.8, 46.5, 31.1, 10.5 and 5.7 %.

Table 3. Mean squares from analysis of variance for calf crop production, longevity, productive and unproductive lifetime in indigenous and crossbred cows

Sources	Df	Longevity	Calf crop production	Productive life	Unproductive life
Cow breed	7	19.2*	11.7**	19.2*	11.7***
Covariate					
Age at first calving	1	61.1**	60.7***	36.2*	
Error Mean square		8.1	4.0	8.1	0.9
Error Df		219	219	219	220
CV (%)		28.3	45.8	45.9	24.2
R^2 (%)		12.3	13.1	8.6	29.9

Significance level *** = P < 0.001 ** = P < 0.01 * = P < 0.05 NS = P > 0.05

Table 2. Least square mean (± SE) calf crop production (number of calves), and longevity, productive and unproductive lifetime (years) in indigenous and crossbred cows

Source of variation	No	Calf crop production	Longevity	Productive life	Unproductive life
Overall mean	228	4.4 ± 0.01	10.1 ± 0.01	6.2 ± 0.01	3.9 ± 0.004
Cow breed		**	*	*	***
Pure Boran	8	3.5 ± 0.75 ^{b}	8.4 ± 1.07 ^{b}	4.5 ± 1.07 ^{b}	5.6 ± 0.33 ^{a}
Boran x Jersey	24	3.9 ± 0.42 ^{b}	8.9 ± 0.59 ^{b}	5.1 ± 0.59 ^{b}	3.3 ± 0.19 ^{de}
Boran x Friesian	22	3.5 ± 0.43 ^{b}	8.9 ± 0.61 ^{b}	5.1 ± 0.61 ^{b}	3.7 ± 0.19 ^{cd}
Boran x Simmental	22	3.7 ± 0.43 ^{b}	9.7 ± 0.62 ^{ab}	5.9 ± 0.62 ^{ab}	3.3 ± 0.19 ^{de}
Pure Horro	75	5.2 ± 0.24 ^{a}	10.8 ± 0.35 ^{a}	6.9 ± 0.35 ^{a}	4.4 ± 0.11 ^{b}
Horro x Jersey	28	4.3 ± 0.39 ^{ab}	10.6 ± 0.56 ^{a}	6.8 ± 0.56 ^{a}	3.1 ± 0.18 ^{e}
Horro x Friesian	30	4.1 ± 0.37 ^{b}	10.4 ± 0.52 ^{ab}	6.5 ± 0.52 ^{ab}	4.0 ± 0.17 ^{bc}
Horro x Simmental	19	4.5 ± 0.47 ^{ab}	9.7 ± 0.66 ^{ab}	5.9 ± 0.66 ^{ab}	3.4 ± 0.21 ^{de}
Covariate		***	**	*	
Age at first calving		-0.56 ± 3.89	0.57 ± 2.74	-0.435 ± 2.11	

Means in a column within a group followed by different letters as a superscript vary significantly

(Significance level *** = P < 0.001 ** = P < 0.01 * = P < 0.05 NS = P > 0.05)

Discussion

Livestock have to both stay alive and reproduce regularly to be of economic interest for the breeder (Essel, 1998). High longevity, long productive life and high calf crop production are good merits of a dairy cow. Different studies

(Alim, 1965; Wagnaar *et al*., 1986; Mekonnen, 1987; Saeed *et al*., 1987, Singh *et al*., 1988; Mukasa-Mugerwa *et al*., 1989; Enyew *et al*., 2000; Gahlot *et al*., 2001; Rizzi *et al*., 2002) reported different values of these traits for different breeds and management conditions.

The overall mean lifetime calf crop production (4.4 ± 0.01 calves) obtained in this study is comparable to the 4.02 (Saeed *et al*., 1987); 5.4 (Alim, 1965); 3 to 5.4 (Mukasa-Mugerwa *et al.,* 1989) and 5.1 (Wagnaar *et al*., 1986) reported for different herds. However, it is higher than the 3.22 ± 0.25 reported by Enyew *et al*. (2000) for crossbred cows with different exotic blood level. Contrary to the findings of Enyew *et al*. (2000), breed variation was found significant.

Similar breed differences for longevity were reported for dairy and beef cattle (Freedeen *et al*., 1981; Weise *et al*., 1985; Silva *et al*., 1986; Rhorer *et al*., 1988). According to Cunningham and Syrstad (1987) the breed variation could be related to the adaptability of zebu and breeds with high proportion of *Bos indicus* gene to a harsh environment because of their heat tolerance, low metabolic rate and disease and parasite resistance. The lifetime performance observed for Horro cows supports the idea suggested by Cunningham and Syrstad (1987). However, the Boran cows, despite being a local breed performed poorer than the Horro and the crossbreds. This variation might have been attributed to the lower number of observations considered in this study. Imported genotypes/breeds generally have lower number of calving and shorter lifespan than local breeds (Vaccaro, 1990). From a comparison among European dairy breeds in tropical and subtropical countries, Holsteins showed a shorter lifespan than Brown Swiss and Jersey cows in Latin America (Vaccaro, 1990). The highest calf crop produced by Horro cows compared to the other breeds could be related to higher stresses due to increased lactation yield in the crossbred cows than the Horro cows as reported by Sendros *et al*. (1987).

The overall mean longevity was 10.1 ± 0.01 years and was significantly ($p < 0.05$) different among the breeds. This value is higher than the reports of different studies (Mukasa-Mugerwa *et al*., 1989; Sahota and Gill, 1991; Enyew *et al*., 2000; Gidey, 2001). Enyew *et al*. (2000) reported a herd life (longevity) of 6.02 ± 0.4 years for Friesian crosses of 50 to 87.5 percent exotic blood level in Ethiopia. Similarly, Mekonnen (1987) reported higher values of 11.7 years for Boran cows. Singh *et al*. (1988) also reported a mean herd life

(time taken from first calving to the completion of five lactations) of 5.7 years for Sahiwal and Jersey Sahiwal crosses. The variation among the different reports could be attributed to various factors. Differences in the definition of longevity given by different authors could have resulted in different values for the trait. Besides, other genetic and non-genetic factors could also have contributed to this variation.

The breed differences in longevity observed in this study agrees with the reports of Rohere *et al*. (1988) and Kumar and Reddy (1989) and contradicts to what Enyew *et al.* (2000) and Singh *et al*. (1988) reported. This difference could be attributed to the higher heterosis effect exhibited by the first crosses than the indigenous breeds (Rohere *et al*., 1988; Kumar and Reddy, 1989). Kumar and Reddy (1989) working on Karan Swiss and Karan Fries cattle with different levels of exotic inheritance reported a longer herd life for F_1 breed group and they attributed this variation to the higher heterosis effect exhibited by the first cross. In this study, the highest longevity was recorded for the Horro breed compared to the crossbreds, which might be related to the earlier age at first calving, shorter postpartum anoestrus interval, days to first service and calving interval reported for the Horro cows compared to the crossbred cows (Gebregziabher, 2001, Gebregziabher *et al.,* 2004). Gidey (2001) reported longevity for Fogera cows of 9.5 years and unproductive herd lifetime of 5.9 years. The longevity reported for Boran cows (Mokonnen *et al*., 1987) kept under ranch condition is higher than the value obtained in this study (8.4 ± 1.07 years) for the same breed. This could be related apart to the lower number of observations considered in this study, to the area of adaptation and management expressed in terms of culling policy of the two farms. In the tropics, survival is influenced by genetic and non-genetic factors. Breed differences and heterosis are important sources of variation in the length of productive life. According to Arthur *et al*. (1993) longevity of both crossbred and synthetic groups is usually greater than that of purebred cows reared in the tropics or under range condition.

Age at first calving was related to overall calf crop production, longevity and productive lifetime of the cows. Similar relationships have been reported by different authors (Pinney *et al*., 1962; Meaker *et al*., 1980; Gahlot *et al*., 2001; Rizzi *et al*., 2002). A one-year increase in age at first calving resulted in a reduction in lifetime calf crop production and productive lifetime at a rate of 0.56 and 0.435, respectively, while longevity increased at a rate of

0.57 (Table 2). Rizzi *et al*. (2002) reported a positive relationship between age at first calving and herd life, the regression coefficients being 0.72 and 0.53 months of herd life in Carora and Holsteins, respectively. On the contrary, age at first calving was negatively correlated with productive lifetime and number of calving in Carora and Holsteins. Africander heifers calving first at two-years old produced 0.6 more calves over their productive lifetime than those calving first at three years old (Meaker *et al*., 1980), while Pinney *et al*. (1962) estimated the increase to be 0.8 of a calf. Both estimates are comparable to the result of the present work.

In conclusion, the lifetime traits estimated in this study is higher than most studies and comparable to others few works. The breed variation observed in lifetime traits and the effect of age at first calving on those traits suggests choice of appropriate breed for the area and reduction of age at first calving. The crossbreds, apart from their superiority over the indigenous breeds (Boran and Horro) in milk yield and other growth and reproductive parameters, showed comparable performance in the lifetime traits considered in this study. Thus, use of crossbred cows is a better option for high overall productivity of the animals.

Acknowledgements

The study is based on data collected on experimental cattle at Bako Agricultural Research Center, for which the author is part and parcel of the research activities going on in the centre. Thus, I would like to express my gratitude to the centre for allowing me to use the data and the staff members of the animal production division who have been involved in the data collection.

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Eth. J. Anim. Prod. 6(1) - 2006: 67-82

Feed Intake, Water Balance and Water Economy in Highland Sheep Fed teff (*Eragrostis teff*) Straw and Supplemented with Graded Levels of *Leucaena leucocephala*[*]

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Abstract

The purpose of this study was to investigate the effect of *L. leucocephala* supplementation on feed intake, water balance and water economy in highland sheep fed teff straw as basal diet. Sixteen young male sheep of uniform weight were assigned in a completely randomized design to the following feeding treatments: *ad libitum* teff straw (T_1, control), supplemented with 60 (T_2), 120 (T_3) or 180 (T_4) g head^{-1}day^{-1} air dried leaves of *L. leucocephala*. Supplementation increased straw ($p<0.01$) and total feed ($p<0.001$) intakes, total water turnover as well as all avenues of water gains and losses ($p<0.001$). Compared with the mean daily DMI of 338 g and 633 ml total water turnover rate of sheep in T_1, sheep in T_4 consumed 49% more DM and turned over 54% more water. Drinking water was the major avenue of water intake (80%; 511 ml in T_1 vs 1108 ml in T_4), followed by metabolic water (15%; 91 ml in T_1 vs 201 ml in T_4) and preformed water (5%; 31 ml in T_1 vs 65 ml in T_4). From the out put side, water loss was highest through evaporation (55%; 330 ml in T_1 vs 767 ml in T_4) followed by urine (27%; 166 ml in T_1 vs 389 ml in T_4) and faecal (18%; 137 ml in T_1 vs 218 in T_4) water. Supplementation was accompanied by liberal water use and resulted in low water economy; the control sheep (T_1), drunk 46% of the water intake of sheep in T_4 and thereby saved 54% more water or 60 liters of water/100 sheep which could serve 119 additional sheep. The results of the study showed the potential of *L. leucocephala* as supplement to poor quality roughages and the importance of liberal water supply along with the supplementary feeding.

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[*] A paper dedicated to the senior author who passed away untimely.

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Key words: Highland sheep; Teff straw; *L.leucocephala*; Feed intake; Water balance; Water economy

Introduction

Sheep production in Ethiopia represents a significant part of the national economy. About 18 million (75%) of the 24 million sheep population is found in the highlands, which carries about 45% of the total land area and over 80% of the livestock and the human population (Getachew Felleke, 1987). Although there are various and complex constraints to sheep production, the most important limiting factor is nutrition. Livestock feeding is based almost entirely on native pasture and crop residues, the quantity and quality of which is subjected to great seasonal variations. Another serious problem that compounds the nutritional problem is water scarcity. During the dry hot season, feeds are dry, water requirement is high, and animals depend for their water supply on permanent water sources, which are unevenly and sparsely distributed perennial rivers and lakes. Thus, it is not uncommon for livestock to go for days without adequate drinking water, which, coupled with poor water quality (pollution/salinity), could cause considerable degrees of dehydration and physiological stress affecting survival as well as productivity.

In view of the variety of its function, water ranks far above every other substance in the body as regards rate of turnover and magnitude of requirement. Water requirements of sheep have been studied under a variety of conditions and requirement varies depending on breed (Wilson, 1970; Degen, 1977; Gupta and Acharya, 1987), physiological condition (Degen, 1977; Aganga *et al*., 1990), amount and composition of feed consumed (Wilson, 1970; Degen and Young, 1981; Bass, 1982; Banda and Ayoade, 1986; Abdelatif and Ahmed, 1992; Sirohi *et al*., 1977) and climatic conditions (Wilson, 1970; Degen, 1977; Degen and Young, 1981; Abdelatif and Ahmed, 1992). Accordingly, there is a great need to study water metabolism and its requirements for sheep under different circumstances. However, except the work of Nuwanyakpa *et al.* (1986), there is no information on any aspect of water metabolism in Ethiopian highland sheep. The purpose of this study was therefore to make up for the paucity of information by assessing the effects of *Leucaeana leucocephala* supplementation on feed intake, water balance and water economy in highland sheep fed teff straw as basal diet.

Materials and Methods

The study was conducted at the Debre Zeit Agricultural Research Centre, which is located 45 km south east of Addis Ababa at an altitude of 1850 masl, $8^0$47`N latitude, and $38^0$59'E longitude. The climatic conditions during the experimental period are presented in Table 1. The experiment was arranged in a completely randomized design (CRD), with four feeding treatments and four observations per treatment. Sixteen young male highland sheep of uniform body weight (average 15 Kg) were divided into four similar body weight groups of four animals each, and the groups were then randomly assigned to one of the following four feeding treatments: a*d libitum* teff straw (treatment 1 [T_1], control), supplemented with 60 (T_2), 120 (T_3) or 180 (T_4) g head^{-1}day^{-1} air dried *Leucaena leucocephala* leaves. The study consisted of 90 days feeding trial followed by 7 days metabolism trial. Data on water balance were collected during the metabolism trial.

Table 1. Climatic conditions during the experimental period (05-11 October 1992)

Parameters	Date							mean±sd
	5	6	7	8	9	10	11	
Min. temp. (^{0}C)	14.5	15.0	15.0	15.0	10.0	15.0	14.0	14.1±1.8
Max. temp. (^{0}C)	22.5	24.0	24.0	25.0	24.0	25.0	23.0	23.9±0.93
Relative humidity (%)	60.3	54.5	54.8	63.5	58.8	72.3	62.8	61.0±6.1
Sunshine (h)	8.2	9.4	8.5	5.2	9.6	1.2	3.0	6.5±3.3
Rainfall (mm)	0.0	0.0	0.0	2.3	0.0	0.0	21.5	23.8
Evaporation (mm)	0.5	0.0	0.0	78.8	76.8	71.4	0.0	32.5±40.4
Wind velocity (km/s)	713.3	714.8	716.4	717.9	718.5	720.1	721.1	717.4±2.8

Source: ILCA (now ILRI) weather station (1 km from the study site)

Animals were housed in a barn with individual metabolism crates, designed to facilitate separate collection of faeces and urine. The supplement was offered at 0800 h and the basal feed an hour latter daily *ad libitum*. Feeds offered and refused were measured daily, and daily intake was calculated by difference on individual animal basis. Samples of feeds offered and refused were collected daily, bulked and sub-sampled separately on individual animal basis at the end of the trial for chemical analysis. Clean water was served in buckets for a duration of one hour, twice daily, at 10:00 h and 1600 h. Water offered and refused on each watering time was measured in a graduated cylinder and recorded individually, and the daily water intake obtained by difference. Animals were weighed at the beginning and the end of the balance trial, during morning hours prior to feeding and watering using a spring balance. Total daily faecal and urine outputs from each animal were collected separately at the same time each day, before the

morning feeding. Urine was collected through a sheet metal tray made to funnel down urine in to a collection bottle. The daily urine output from each sheep was measured volumetrically and recorded, from which 25% was preserved for further analysis. Total daily faecal output was collected in a separate sheet metal tray, weighed and recorded on an individual sheep basis and about 50% of the daily out put was bulked and preserved for further analysis.

Feed and faecal samples were analyzed for neutral detergent fiber (NDF) following the procedures of Van Soest and Robertson (1985) and for dry matter (DM), ash and nitrogen according to AOAC (1970). Water balance was considered to be the balance between water gain (drinking, preformed and metabolic water) and water loss (faecal, urinary and evaporative water). Metabolic water available from metabolism of nutrients was calculated by applying the factors of 0.40, 0.56 and 1.07 (ml g^{-1} digestible nutrient) for proteins, carbohydrates and fats, respectively (Maynard *et al*., 1981). Total water turnover was computed as the sum of free water, feed water and metabolic water. Evaporative water was calculated as the difference between the total water turnover and the losses in faeces and urine. Data were subjected to a one-way analysis of variance, and group differences were compared by Duncan`s New Multiple Range Test. All analyses were done using the General Linear Model (GLM) procedures (SAS, 1989).

Results

The chemical composition of the experimental feeds is presented in Table 2. The intakes of DM and DM components by sheep as affected by *L. leucocephala* supplementation are presented in Table 3. *L. leucocephala* contained considerably lower NDF (high soluble fraction) and higher CP, and relatively higher ash than teff straw. *S*upplementation increased intakes of straw ($p<0.01$) and total ($p<0.001$) DM, NDF, CP and ash. Intakes of DM and DM components from straw were not different ($p>0.05$) between the supplemented groups, and there was a declining trend beyond T_3. Intakes of total DM and total ash were higher ($p<0.05$) in T_4 than T_2, but, while the total NDF intake was not different ($P>0.05$), CP intake differed linearly ($p<0.05$) between supplement groups.

Data on water balance are presented in Tables 4 and 5, where all avenues of water gains and losses increased with supplementation, *al biet* at variable magnitudes. Absolute and relative water intakes from feed (preformed

water), metabolism (oxidation) and drinking (free water) and the relative contribution (% of total water intake) of each sources of water intake are presented in Table 4. Supplementation significantly increased feed water intake from straw ($p<0.01$) and the total feed ($p<0.0001$), but differences were not significant ($P>0.05$) among the supplemented groups in water intake from straw, between T_2 and T_3 in absolute total feed water intake, and between T_3 and T_4 in all parameters. Supplementation also produced higher ($p<0.0001$) metabolic water gain than the control group, but differences in all parameters were not significant ($p>0.05$) between T_3 and T_4. As in the case of the other sources of water intakes, drinking water considerably increased with supplementation. Except water turnover as a ratio of dry matter intake, where the increase was non-significant ($p>0.05$), supplementation had highly significant ($P<0.0001$) effect on the other parameters. However, differences were not significant ($p>0.05$) between T_2 and T_3 or between T_3 and T_4 in all parameters.

Table 2. Chemical composition of the experimental feeds

Components	*Teff* straw	Leucaena leucocephala
DM (g kg^{-1} as fed)	917.0	895.2
(g kg^{-1} DM)		
NDF	816.7	269.5
CP	27.5	279.4
Ash	79.0	100.9

DM = Dry matter; NDF = Neutral detergent fibre; CP = Crude protein (nitrogen x 6.25)

Although there was a significant increase in all avenues of water intakes in absolute terms (ml), as a ratio of body weight (ml/kg W) or metabolic body size (ml/kg $W^{0.82}$) with supplementation, their relative contribution (%) to the total water intake were not different between treatments ($p>0.05$). The mean daily total water turnover obtained from the three water sources is shown in Table 4. Supplementation increased water turnover rate considerably ($p<0.0001$). The increase in total water turnover and the magnitude of group differences generally followed the trends of the drinking water, except that the water turnover of T_4 was higher ($p<0.05$) than T_3 in absolute terms and as a ratio of metabolic body size.

The mean daily losses of water through faeces, urine and evaporation are presented in Table 5. Supplementation with *L. leucocephala* increased faecal water loss both in absolute terms ($p<0.001$) and as a ratio of metabolic body size ($p<0.05$), differences being significant ($p<0.05$) between the control and the supplemented groups in absolute faecal water loss, and between T_1 and

T_4 in the later parameter. On the other hand, while faecal water loss as a ratio of body size showed a non-significant increase with supplementation, there were no marked treatment differences ($p>0.05$) in faecal water content. Conversely, the contribution of faecal water to the total water loss declined ($p<0.05$) with supplementation, being higher ($p<0.05$) in T_1 than in T_4. Urine water output also increased ($p<0.01$) with supplementation. Urine loss in absolute terms was lower ($p<0.05$) in the control than the supplemented groups and in T_2 than in T_4, while differences as a ratio of body weight or metabolic body size were not significant ($p>0.05$) between T_1 and T_2 or among the supplemented groups. On the other hand, the contribution of urine water to the total water loss increased non-significantly with supplementation. Evaporative water loss both in absolute and relative terms considerably increased with supplementation ($p<0.0001$). In all parameters considered, the control group lost significantly less evaporative water than the supplemented groups, and T_2 less than T_4. Like the urine water loss, the contribution of evaporative water to the total water loss showed a non-significant increase with supplementation.

Table 3. Mean daily feed intakes (mean±sd) in sheep fed *teff* straw and supplemented with graded levels of *L.leucocephala*

Components	Level of *L.leucocephala* supplementation (g as fed head^{-1} day^{-1})						LS
	0 (T_1)	60 (T_2)	120 (T_3)	180 (T_4)	Mean	SEM	
DMI							
L.leucocephala(g)	0	53.7	107.4	161.2			
Straw	338.1±42.9^{B}	505.8±64.4^{A}	515.6±45.6^{A}	507.1±69.8^{A}	466.7	28.9	**
Total (g)	338.1±42.9^{C}	559.5±64.4^{B}	623.0±45.6^{AB}	668.3±69.8^{A}	547.3	28.9	****
(g/kg W)	21.8±0.40^{C}	31.1±0.39^{B}	33.8±1.44^{AB}	34.6±3.5^{A}	30.3	0.96	****
(g/kg W$^{0.75}$)	43.2±1.82^{C}	63.9±2.54^{B}	70.0±1.44^{A}	72.4±6.9^{A}	62.4	1.92	****
NDFI (g)							
L.leucocephala	0	14.5	29.0	43.4			
Straw	276.2±35.0^{B}	413.1±55.1^{A}	421.1±37.3^{A}	414.2±57.0^{A}	381.2	23.6	**
Total	276.2±35.0^{B}	427.6±55.1^{A}	450.0±37.3^{A}	457.6±57.0^{A}	402.9	23.6	***
CPI (g)							
L.leucocephala	0	15.0	30.0	45.0			
Straw	9.3±1.2^{B}	13.9±1.9^{A}	14.2±1.3^{A}	14.0±1.9^{A}	12.9	0.79	**
Total	9.3±1.2^{D}	28.9±1.9^{C}	44.2±1.3^{B}	59.0±1.9^{A}	35.4	0.79	****
Ash (g)							
L.leucocephala	0	5.4	10.9	16.2			
Straw	26.7±3.4^{B}	40.0±5.3^{A}	40.7±3.6^{A}	40.1±5.5^{A}	36.9	2.3	**

DMI = Dry mater intake; NDFI = Neutral detergent fibre intake; CPI = Crude protein intake; SEM = Standard error of the mean; LS = Level of significance (p) NS = Not significant (p>0.05); ** p<0.01; *** p<0.001; **** p<0.0001

^{A,B,C,D} Means followed by different superscripts in the same row are significantly different (p<0.05)

Table 4. Mean daily water intakes and total water turnover (mean±sd) in sheep fed *teff* straw and supplemented with graded levels of *L.leucocephala*

Parameters	Level of *L.leucocephala* supplementation (g as fed head^{-1} day^{-1})						LS
	0 (T_1)	60 (T_2)	120 (T_3)	180 (T_4)	Mean	SEM	
I. Water intakes							
A. Preformed water							
L.leucocephala (ml)	0	6.3	12.5	18.9			
Straw (ml)	30.6±3.9^{B}	45.8±6.1^{A}	46.7±4.1^{A}	45.9±6.3^{A}	42.2	2.6	**
Total (ml)	30.6±3.9^{C}	52.1±6.1^{B}	59.2±4.1^{AB}	64.8±6.3^{A}	51.7	2.6	****
ml/kg W	2.0±0.03^{C}	2.9±0.03^{B}	3.2±0.15^{A}	3.4±0.33^{A}	2.9	0.09	****
ml/kg W0.82	3.2±0.11^{C}	4.9±0.14^{B}	5.4±0.15^{A}	5.7±0.52^{A}	4.8	0.14	****
% total intake	4.8±0.44	4.9±0.29	5.0±0.22	4.7±0.40	4.9	0.17	NS
B. Metabolic water							
ml	91.3±10.4^{C}	154.0±23.3^{B}	186.0±9.6^{A}	200.6±13.4^{A}	158.0	7.6	****
ml/kg W	5.9±0.48^{C}	8.5±0.38^{B}	10.1±0.66^{A}	10.4±1.1^{A}	8.7	0.35	****
ml/kg W0.82	9.7±0.75^{C}	14.3±0.92^{B}	17.1±0.80^{A}	17.7±1.7^{A}	14.7	0.55	****
% total intake	14.5±2.0	14.5±0.45	15.5±0.36	14.7±1.5	14.8	0.63	NS
C. Drinking water							
ml	511.5±65.6^{C}	862.9±150.2^{B}	952.9±44.5^{AB}	1108.2±115.2^{A}	858.9	51.3	****
ml/g DMI	1.52±0.17	1.53±0.09	1.54±0.08	1.67±0.20	1.57	0.07	NS
ml/kg W	33.1±3.2^{C}	47.7±3.5^{B}	51.9±4.7^{AB}	57.2±4.3^{A}	47.5	1.98	****
ml/kg W$^{0.82}$	54.1±4.9^{C}	80.3±7.3^{B}	87.5±6.3^{AB}	97.5±7.3^{A}	79.9	3.3	****
% total intake	80.7±2.3	80.6±0.71	79.5±0.58	80.6±1.9	80.4	0.78	NS
II.Total water turnover							
ml	633.4±71.5^{C}	1069.0±179.3^{B}	1198.1±55.9^{B}	1373.6±119.2^{A}	1068.5	58.4	****
ml/g DMI	1.88±0.16	1.90±0.10	1.93±0.10	2.07±0.19	1.95	0.07	NS
ml/kg W	41.0±2.9^{C}	59.1±3.9^{B}	65.2±5.5^{AB}	71.0±4.5^{A}	59.1	2.2	****
ml/kg W$^{0.82}$	67.0±4.4^{C}	99.5±8.4^{B}	110.0±7.2^{B}	121.0±7.4^{A}	99.4	3.5	****

SEM = Standard error of the mean; LS = Level of significance (p); NS = Not significant (p>0.05); ** p<0.01; **** p<0.0001

^{A,B,C} Means followed by different superscripts in the same row are significantly different (p<0.05)

By comparing the drinking water intake with the overall mean free water intake of T_4 (reference value), the relative water economies on the different treatments were calculated, and the results are presented in Table 4. Sheep on T_1, T_2 and T_3, respectively, drunk 46, 78 and 86 % as much water as T_4, thereby saving 54, 22 and 14% water or 60, 25 and 16 liters of water per 100 sheep, which could respectively serve additional 119, 32 and 17 sheep compared with T_4. In all comparison considered, there was more water saving ($p<0.0001$) in the control than the supplemented groups and in T_2 than in T_4, but T_3 did not differ ($p>0.05$) in water economy from either T_2 or T_4.

Table 5. Mean daily water losses and water economy (mean±sd) in sheep fed *teff* straw and supplemented with graded levels of *L.leucocephala*

Parameters	Level of *L.leucocephala* supplementation (g as fed head^{-1} day^{-1})						LS
	0 (T_1)	60 (T_2)	120 (T_3)	180 (T_4)	Mean	SEM	
I. Water losses							
A. Faecal water							
% moisture	53.8±6.8	51.5±3.5	51.7±3.7	52.8±3.6	52.5	2.3	NS
ml	137.4±21.5^{B}	192.0±19.1^{A}	202.0±13.5^{A}	217.5±31.4^{A}	187.2	11.2	**
ml/kg W	8.9±1.3	10.8±1.6	11.0±1.6	11.3±2.1	10.5	0.82	NS
ml/kg W0.82	14.6±2.0^{B}	18.1±2.4^{AB}	18.6±2.4^{AB}	19.3±3.3^{A}	17.6	1.28	*
% total loss	21.9±4.6^{A}	18.4±3.7^{AB}	16.9±1.5^{AB}	15.9±2.3^{B}	18.3	1.63	*
B. Urinary water							
ml	166.4±5.6^{C}	285.0±96.1^{B}	325.4±60.5^{AB}	388.9±111.3^{A}	291.4	39.7	**
ml/kg W	10.9±1.3^{B}	15.6±3.8^{AB}	17.6±2.5^{A}	19.9±4.3^{A}	16.0	1.61	**
ml/kg W0.82	17.7±1.8^{B}	26.4±6.9^{AB}	29.7±4.3^{A}	34.0±7.8^{A}	27.0	2.84	**
% total loss	26.5±3.0	26.4±5.4	27.1±4.1	28.0±5.8	27.0	2.34	NS
C. Evaporative water							
ml	329.6±75.5^{C}	592.0±112.4^{B}	670.7±24.0^{AB}	767.1±73.3^{A}	589.9	39.0	****
ml/kg W	21.2±3.7^{C}	32.7±3.6^{B}	36.6±4.1^{AB}	39.8±4.9^{A}	32.6	2.06	***
ml/kg W0.82	34.7±6.2^{C}	55.0±6.8^{B}	61.7±5.7^{AB}	67.8±7.9^{A}	54.8	3.34	****
% total loss	51.6±6.5	55.2±3.9	56.0±2.6	56.1±6.1	54.7	2.52	NS
II. Water economy							
%	53.9±5.9^{A}	22.1±13.6^{B}	14.0±4.0^{BC}	0.0±10.4^{C}	22.5	4.63	****
L water/100 sheep	59.7±6.6^{A}	24.5±15.0^{B}	15.5±4.5^{BC}	0.0±11.5^{C}	24.9	5.13	****
Additional sheep served	119.3±27.0^{A}	31.7±25.1^{B}	16.5±5.3^{BC}	0.0±10.9^{C}	41.9	9.7	****

SEM = Standard error of the mean; LS = Level of significance (p)

NS = Not significant (p>0.05); * p<0.05; ** p<0.01; **** p<0.001**** p<0.0001

^{A,B,C} Means followed by different superscripts in the same row are significantly different (p<0.05)

Discussion

Sheep productivity in the Ethiopian highlands is suppressed by inadequate feed and water supplies and poor utilization of agro-industrial by-products (Nuwanyakpa *et al.,* 1986). The chemical compositions of the feeds used in this study were within the range of reported values for teff straw (Nuwanyakpa *et al*., 1986; Bonsi *et al*., 1994; Osuji *et al.,* 1995) and *L. leucocephala* (Banda and Ayaoade, 1986; Bonsi *et al*., 1994). The high CP and soluble content of *L. leucocephala* indicates its high nutritive value and potential as supplement to poor quality roughages.

As expected, *L. leucocephala* supplementation increased intakes of straw and total DM and DM components. The trends observed in the intakes of the basal and the total diet with supplementation were consistent with previous reports when *L. leucocephala* was supplemented to maize stover (Banda and Ayaode, 1985) or teff straw (Bonsi *et al*., 1994). The declining trend in straw

intake beyond T_3 could be due to substitution effect. The positive effects of supplementation on feed intake may have been a reflection of the increase in the intake of essential nutrients such as energy, vitamins minerals and in particular nitrogen (N). Leguminous fodder trees, as supplements, alleviate N deficiency thereby improving the rate of degradation of the basal diet and the fractional rate of liquid matter from the rumen and hence feed intake (Bonsi *et al.,* 1994). Moreover, leguminous fodder trees increase protein supply to the host animal by increasing the supply of both degradable and undegradable protein, and by creating a favorable rumen environment resulting in enhanced fermentation of the basal roughage and thus increased microbial protein synthesis (Osuji *et al.,* 1995).

It has been suggested that *L. leucocephala* can be used successfully when supplemented at levels of 30-40% of the total diet of small ruminants (Banda and Ayaode, 1986; Bonsi *et al*., 1994). In this study, T_4 (180 g), which constituted 33 percent of the total diet, seemed to be the optimum level of *L. leucocephala* supplementation. On the other hand, supplementation may induce changes in water metabolism and water requirements and in related physiological responses in water balance.

Accounting for about 99 percent of all molecules and 73 percent of the fat free empty body mass (King, 1983), water is by far the largest single chemical component of the animal body. This water present in largest proportion in the body is not merely a bland inert liquid or accidental space filler, but is a highly active and essential structural constituent. From a functional point of view, no other chemical compound has so many distinct and vital roles as water; by far the greatest number of life processes in the body takes place with water as a key substance. Accordingly, water stands second only to oxygen of all environmental constituents immediately necessary for life, which is substantiated by the fact that while an animal may survive a loss of practically all of its body fat and over half of its protein, a loss of one tenth of its body water is fatal (Maynard *et al*., 1981). Since relatively small changes in body water cause profound changes in function, the body water content must remain reasonably constant. The constancy depends on a balance between gain and loss of water by the body. Water is gained from feed, drinking and metabolism, and it is lost through faeces and urine periodically and by evaporation constantly.

Water contained from feeds consumed (preformed water) is highly variable from feed to feed according to the moisture content, which can range from as low as 5 percent in dry feeds to as high as 90 percent or more in succulent feeds (Sirohi *et al.,* 1997), and the amount of the feed consumed. Water derived from dry feeds may be insignificant compared to the total water intake, while that obtained from succulent feeds can supply all the water needs. Sheep would ingest little or no drinking water when the water content of the feed is over 70 percent (Degen, 1977; Sirohi *et al*., 1997). In our study, water ingested through the feed constituted the least source of the total water input (5 percent), and this was attributed mainly to the low moisture content of the experimental diets. On the other hand, supplementation increased water ingested from the feed. In the absence of appreciable difference in the moisture content of the experimental feeds, the observed group differences in preformed water intakes almost exclusively paralleled differences in feed intake.

The oxidation of organic nutrients during metabolic processes in the body leads to the formation of water (metabolic water) from the hydrogen present. On the average fats, carbohydrates and proteins, respectively yield 1.07, 0.56 and 0.40 ml water per gram oxidized, or an equivalent of 0.12, 0.14 and 0.10 ml water per kcal metabolizable energy derived from oxidation (Maynard et al., 1981). Metabolic water may account for up to 15% of the total water intake in sheep (Aganga *et al.,* 1989; Abdelatif and Ahmed, 1992; Sirohi *et al.,* 1997) and remains constant provided metabolic rate is constant (Maynard *et al.,* 1981). In this study, metabolic water was the second avenue of water intake (15%), and considerably increased with supplementation. The observed treatment effect on metabolic water intake appeared to parallel differences in feed intake and could be attributed to the same reason described for preformed water intake. Additionally, differences in the digestibility of feeds with supplementation might have partly contributed to the difference.

The high variability of water obtained from the feed and the relative constancy of metabolic water follow that preformed water and drinking (free) water intakes are of necessity complementary. Accordingly, when water content of the feed ingested is low, drinking water is the major source of water intake, and its provision for livestock becomes the main concern. In our study, drinking water constituted the major avenue of water intake (80%), and the volume consumed increased with supplementation. Compared

with the intake of 511 ml in sheep fed teff straw alone, sheep supplemented with 60, 120, 180 g *L. leucocephala*, respectively, drank 41, 46 and 54% more water in absolute terms. Similarly, when body weight differences between groups were discounted, T_4 consumed 42 or 45% more water per kg W or per kg $W^{0.82}$, respectively, than the control group. The increase in drinking water intake with supplementation is in agreement with previous findings and is due to the increase in feed intake.

It is generally agreed that water requirements are correlated with feed intake; as feed intake decreases or increases, there is a concomitant change in faecal, urinary and evaporative water losses and, accordingly, in water requirement (Wilson, 1970; Degen and Young, 1981; Abdelatif and Ahmed, 1992; Sirohi *et al.,* 1997). Because of the close and direct relationship between dry matter and water intakes, it has been customary to express water requirements as a ratio of dry matter intake. It was, however, recognized that with a constant dry matter intake, the ratio of water intake to DMI (ml g^{-1} DMI) increased with supplementation ($p>0.05$; 1.52 in T_1 vs 1.67 in T_4), suggesting that supplemented groups required more water per unit DM consumed than the control. Such observation was a reflection of the composition of the ingested dry matter, ash and in particular nitrogen (Table 2). Sheep reportedly require more water on high-protein than on a low-protein diet, since the nitrogenous end products require a larger urine volume for excretion (Wilson, 1970; Bass, 1982; Banda and Ayaode, 1986; Nuwanyakpa *et al.,* 1986; Abdelatif and Ahmed, 1992; Sirohi *et al.,* 1997). Similarly, the higher the proportion of salt or other minerals in the diet of sheep, the larger the urine excretion and, accordingly, the larger the water requirement (Wilson, 1970; Abdelatif and Ahmed, 1992; Sirohi *et al.,* 1997).

Summing up all avenues of water intakes, sheep supplemented with 120 g *L. leucocephala* (T_4) turned over 54, 9, 42 or 45% more water in absolute terms, per unit DMI, as a ratio of body size or per kg $W^{0.82}$, respectively, than sheep fed teff straw alone (T_1). In general, the pattern of the total water turnover was similar to the drinking water intake, and the greater water need with supplementation was attributed to the greater loss of water through faeces, urine and evaporation, as explained for drinking water intake.

Faecal water constituted the least avenue of water loss (18%), which agrees with previous reports that with normally hydrated sheep feacal water accounts for up to one fourth of the total water loss (Degen and Young, 1981;

More *et al*., 1983; Aganga *et al*., 1989; Abdelatif and Ahmed, 1992; Sirohi *et al.,* 1997). Supplementation decreased the relative contribution of faecal water loss, but increased the volume of faecal water. The loss of water through the faecal route is determined by the total amount of faeces voided and the moisture content of the excreted faeces. The moisture content of the faeces found in this study falls within the range reported for sheep (Degen and Young, 1981; Umunna *et al.,* 1981; Aganga *et al.,* 1989), and was not affected by supplementation. In the absence of group differences in faecal moisture content, the increase in faecal water loss was largely due to the increase in feed intake accompanying supplementation, and group differences could be attributed to the corresponding difference in feed intake.

Urine water loss was the second avenue of water loss (27%), and the volume increased with supplementation. The increase in urinary water loss with supplementation could be related to the higher DMI as well as nitrogen and ash intakes, which result in a greater urinary water for the excretion of mineral and nitrogen end products. Previous studies also show that urinary water accounts for up to one third of the total water loss in sheep (Degen and Young 1981; More *et al*., 1983; Aganga *et al.,* 1989; Abdelatif and Ahmed, 1992; Sirohi *et al*., 1997).

Evaporative water loss represents the remainder of the water loss not collected in faeces and urine, and includes water presumably lost through respiration, perspiration and evaporation from the respiratory tract and the skin. Insensible perspiration and non-panting respiratory water losses are obligatory, whereas losses by panting and sweating come into picture in response to relatively higher thermal stimuli for thermoregulation. Evaporation becomes the major avenue of water loss from the body, particularly under tropical conditions, where evaporative cooling may account for up to three fourth of the total water loss in sheep (More *et al.,* 1983; Aganga *et al.,* 1989; Abdelatif and Ahmed, 1992; Sirohi *et al.,* 1997). In this study, where the environmental conditions were relatively moderate, evaporative water loss still constituted the major avenue of water loss (55%), and increased with supplementation. The increase in metabolic water loss with supplementation could be due to high metabolic rate caused by high feed and/or water intakes/turnover accompanying supplementation. It has been shown that water requirement, respiratory rate and evaporative water output are directly proportional to feed intake as a result of increment in metabolic activities (Aganga *et al.,* 1990). It, therefore, seems that the

amount of water used at low levels of feed intake during supplementation is less than at high levels of intake when metabolic rates and cooling requirements become greater.

The water balance results in general indicate that supplementation increased all avenues of water gains and water losses, but at different magnitude. The increased demand in water turnover/requirement with supplementation was a reflection of the rise in water loss through evaporation and urine, as observed from the decrease in the relative contribution of faecal water loss, but an increase in relative contribution of urine and evaporative water losses with supplementation. Comparison of the relative difference among groups in each avenue of water losses with respect to total water turnover also showed similar trends. Compared with T_2, T_3 and T_4, respectively, T_1 turned over /drunk 41, 47 and 54% less water, and lost 28, 32 and 37 % less faecal water, 42, 49 and 57% less urinary water and 44, 51 and 57% less evaporative water. Because the percentage difference in faecal water between groups was much less than the differences in other parameters, it can be concluded that evaporative water loss followed by urine water loss appeared to be important sources of body water loss during supplementation.

Because of increases in water turnover/intake/loss with supplementation, there was a corresponding decrease in water economy. The magnitude of group differences in water economy followed the same trend with that of the total water turnover and free water intake, but in reverse order. Water economy has significant implications for sheep production where and when water supply is limited in total amount and/or frequency of distribution. The limited availability water, especially during the dry seasons, compels to economize water use in livestock production. One possibility would be to control factors that aggravate water requirement of animals, so as to save water and serve more animals on a daily basis. During adverse conditions, such as drought, when water is required for survival than production, such water saving option will help more animals survive and transit dry/drought periods to normal and rainy seasons. Thus, in the present study, the same volume of water that would serve 100 sheep daily when fed teff straw with 60, 120 or 180 g *L. leucocephala* would maintain 169, 186 or 219 sheep with out supplementation respectively. Similarly, using rough estimation limited to the conditions of this experiment, 18 million sheep in the highlands of Ethiopia would daily require 20,000 m^3 water on 120 g supplement, but only

9,000 m^3 meter water without supplementation, which would save 11,000 m^3 meters water. Another management practice of water saving would be infrequent watering regime. It seemed possible that the daily watering of sheep may better reflect husbandry procedures than water requirements. For example, in the eastern lowlands of Ethiopia at Jijiga, Zewdu Sisay (1991) found that Blackhead Ogaden sheep, watered once every three days, could save 34% more water for 50 additional sheep with out any adverse effect on performance when compared with daily *ad libitum* watering regime. Nuwanykapa *et al*. (1986) also concluded that watering highland sheep once every three days instead of *ad libitum* is an economical and labour-saving "drought response" watering frequency. However, the potential benefits of water economy should be realized in relation to productive parameters, because there would be a trade-off between water saving strategies and production.

In conclusion, sheep supplemented with *L. leucocephala* consumed more feed, turned over more water, gained more water from the feed, metabolism and drinking, and lost more water through the faeces, urine and evaporation than sheep fed teff straw alone. The effect of supplementation consequent upon increased feed intake was manifested through increased drinking water intake and urinary and evaporative water losses. The results of the study showed the potential of *L. leucocephala* as supplement to poor quality roughages and the importance of liberal water supply along with supplementation. The study also demonstrated the interaction between diet and water requirement which could influence the physiological response and hence productivity of sheep. It is therefore recommended that, given the strong relationship between feed and water intakes, any feed improvement/supplementation strategy should also consider the availability of water, or supplementation would rather exacerbate dehydration and physiological stress at times of water scarcity. More work is needed on water requirement of ruminants in relation to the different determinants of water metabolism as well as the various facets of watering regimes and strategies in order to identify optimum and economical watering frequency.

Acknowledgments

The financial support of Debre Zeit Agricultural Research Centre for the study is highly acknowledged. The authors also thank Wro. Asegedech

Dinku for the technical assistance and Staff of ILRI Addis Nutrition Laboratory for the chemical analysis work.

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Eth. J. Anim. Prod. 6(1) - 2006: 85-89

Lifetime Productivity of Horro Ewes Maintained at Bako Agricultural Research Center

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Abstract

Data from 212 ewes with 848 lambing records were used to study lifetime productivity of Horro sheep maintained at Bako Agricultural Research Center. Ewe yearling weight was significantly (at least at $p < 0.05$) affected all the reproduction traits considered, except the total number of lambs weaned per ewe lambing over two parities (NLW2). Twin born ewes tended to produce more number and weight of lambs, though not significant, than did ewes born single. All simple correlations between total weight of lambs weaned per ewe lambing over the first parity (TWW1) and total weight of lambs weaned per ewe lambing over the latter parities were high positive and significant ($p < 0.001$). Selection for total weight weaned per ewe lambing over the first parity (TWW1)could thus be useful to indirectly improve ewe lifetime productivity.

Keywords: Ewe yearling weight; ewe joined; number born; number weaned; weight weaned

Introduction

The total number and weight of lambs produced during the lifetime of breeding female is of major economic importance in any sheep enterprise. The higher the number and weight of lambs weaned per ewe lifetime, the lower the overheads for each animal, and the more resources can be utilised to increasing production. Lifetime ewe productivity is improved through the optimisation of reproduction of ewes, as well as survival and growth of their lambs. Snyman *et al*. (1998) reported that among others, reproduction and survival rates are universally important in any livestock production system. Other traits vary in importance and can, in some situations, be of little or no value.

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In breeds such as the Horro, where sheep are reared solely for meat production, the primary selection objective should be to increase total weight of lambs weaned per ewe lifetime. Total weight of lambs weaned per ewe joined or lambing is a function of the number of lambs born, their survival and the individual lamb weight at weaning (Boujenane *et al*., 1991). In Horro sheep, however, emphasis has mostly been given to the individual component of reproduction such as fertility, litter size and lamb survival rate. Ewe productivity, defined as number or total weight weaned per ewe joined or lambing, which is dependent upon the component traits, has received much less attention both in Horro sheep and other indigenous sheep breeds of the country. According to Snyman *et al*. (1997), there is a relatively large phenotypic variation in total weight of lamb weaned regardless of the reproductive rate of the flock. These authors also indicated that this variation may have a genetic basis and could therefore be exploited to genetically increase lifetime reproductive efficiency in any flock.

Selection for total weight of lamb weaned would result in a correlated genetic increase in weaning weight of individual lambs. Nevertheless, selection for litter size alone would not increase the individual weaning weight of each lamb, which is just as important as the number of lambs weaned (Snyman *et al*., 1996). Total weight of lamb weaned is determined by litter size and several other factors, such as mothering ability and milk production of the ewe, and growth potential of the lamb (Snyman *et al*., 1997).

The objectives of this study were: 1) to determine lifetime productivity of Horro ewes in relation to total number of lambs born and weaned and total weight of lambs weaned per ewe lambing over different lambing opportunities, 2) to investigate the phenotypic relationships between total weight weaned in the first parity and total lifetime production, and 3) to determine whether total weight weaned could be used as an efficient indicator of ewe lifetime productivity.

Materials and Methods

The study Center, Bako, is situated in east Wollega zone, about 250 km west of Addis Ababa on the main road to Nekemte at an altitude of approximately 1650 m above sea level (09° 06´ N and 37° 09´ E). Bako has a hot and humid climate and receives a mean annual rainfall of about 1219 mm, more than 80 % of which is recorded in the months of May to September. Mean monthly maximum and minimum temperatures are about 28°C and 14°C,

respectively, with average temperature of 21°C. Potential evapotranspiration averages 62 mm per month.

Data for this study were obtained from the flock of Horro sheep maintained at Bako Agricultural Research Center. Details regarding the origin, history and management of this flock are described elsewhere by Solomon and Gemeda (2000) and Solomon *et al*. (2002). A total of 212 ewes, born from 1978 to 1991 with 848 lambing records, were used for the study. Reproduction traits used were total number of lambs born per ewe lambing over two to four lambing opportunities (NLB2, NLB3 and NLB4, respectively), total number of lambs weaned per ewe lambing over two to four lambing opportunities (NLW2, NLW3 and NLW4, respectively) and total weight of lambs weaned per ewe lambing over one to four lambing opportunities (TWW1, TWW2, TWW3 and TWW4, respectively). The first four lambings of a ewe were taken as an indication of lifetime reproduction. Data from only those ewes, which gave birth in four consecutive lambings, were considered in the analysis.

Total number of lambs born and weaned and total weight of lambs weaned per ewe lambing over different parities were computed as described by Snyman *et al*. (1997) and Gemeda (2001). For instance, total weight of lamb weaned for each ewe was calculated by adding weaning weights of all lambs weaned by the ewe in a specific lambing year. Total weight weaned over four consecutive lambings was calculated by adding the total weight of lambs weaned per ewe for the first, second, third and fourth lambings. Weaning weight of lambs was recorded at about 90 days.

Total numbers of lambs born and weaned were considered as continuous variables in the present study. This was justified due to the fact that these traits are a combination of two to four separate lambings, which increased the number of categories.

Data were analysed using the GLM procedure of SAS (1996). The model of analyses included fixed effects of type of birth of the ewe (single, twin) and year of birth of ewe (1978 to 1991) and ewe yearling weight as a linear covariable.

Results and Discussions

Analysis of variances and significance of fixed effects and least squares means for reproduction traits are shown in Tables 1, 2, 3 and 4. The analysis

of variance showed that the models of analyses accounted for 11.7 to 18.1 % of the variances in total number of lambs born and weaned and 28.0 to 24.8 % in total weight of lambs weaned per ewe lambing over the different lambing opportunities. Ewe yearling weight significantly (at least at $p < 0.05$) affected all the traits considered, except the number of lambs weaned per ewe lambing over two parities (NLW2). Solomon (1998) who used part of the same data set indicated that yearling weight was significantly related with number and weight of lambs weaned per ewe. No reports on lifetime ewe reproductive performance could be found in the literature either for Horro sheep or the other indigenous sheep breeds of the country for possible comparison. However, study conducted on the Tygerhoek Merino flock (Gemeda, 2001) reported significant effects of ewe two-tooth liveweight (liveweight recorded at about 18 month of age) on ewe lifetime production performance. Cloete and Heydenrych (1987) also suggested that selection for an increased two-tooth liveweight would probably be associated with an increase in reproduction rate.

Type of birth of the ewe was not significantly ($p > 0.05$) related to any of the reproduction traits investigated. Nevertheless, twin born ewes tended to produce more and heavier lambs than did ewes born as singles (Tables 3 and 4). The non-significant effect of type birth of the ewe obtained in the present study was in contrast to those reported by Cloete and Heydenrych (1986) and Gemeda (2001) in Merino flock of the Tygerhoek and by Kritzinger *et al.* (1984) in Dormer and South African Mutton Merino sheep.

Table 1. Analysis of variance and level of significance for number of lambs born and weaned over different lambing opportunities

Source	df	Mean square and level of significance					
		NLB2	NLB3	NLB4	NLW2	NLW3	NLW4
Birth type of ewe	1	0.0622^{NS}	0.03224^{NS}	1.5825^{NS}	0.5837^{NS}	0.7444^{NS}	3.5682^{NS}
Birth year of ewe	13	1.4231***	2.5652***	2.9834*	0.5286^{NS}	1.7629*	2.2207^{NS}
Ewe yearling weight (kg)	1	2.3617*	7.2025***	8.2680*	0.4541^{NS}	5.9120**	7.0812*
Mean square error		0.529	1.032	1.565	0.474	0.908	1.574
R^2 (%)		16.82	16.86	13.10	11.66	18.07	13.19
C.V. (%)		27.54	24.70	22.63	30.41	28.30	29.10

^{NS} = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

NLB2, NLB3, NLB4= Number of lambs born per ewe lambing over 2, 3 and 4 lambing opportunities, respectively. NLW2, NLW3, NLW4= Number of lambs weaned per ewe lambing over 2, 3 and 4 lambing opportunities, respectively.

The numbers of lambs born and weaned per ewe lambing over four lambing opportunities (NLB4 and NLW4, respectively) obtained in the current study were comparable to those reported by Gemeda (2001) in the Tygerhoek Merino flock. The total weight of lambs weaned per ewe lambing over four

lambing opportunities (TWW4) reported by this author was, however, higher than the values reported in the present study. This may be due to differences in body size between the two breeds. For example, the mean weaning weight reported for Horro sheep was 11.8 kg (Solomon and Gemeda, 2000), while that of the Tygerhoek Merino flock was 22.9 kg (Gemeda, 2001).

Table 2. Analysis of variance and level of significance for total weight weaned over different lambing opportunities

Source	df	Mean square and level of significance			
		TWW1	TWW2	TWW3	TWW4
Birth type of ewe	1	7.1843 ^{NS}	142.3578^{NS}	194.850^{NS}	675.981^{NS}
Birth year of ewe	13	98.4801***	271.3715***	813.137***	971.023***
Ewe yearling weight (kg)	1	96.8883*	257.0272*	1341.198***	1410.643**
Mean square error		23.294	71.190	129.682	208.905
R^2 (%)		28.13	27.99	34.80	28.08
C.V. (%)		33.18	29.98	27.66	27.91

^{NS} = not significant; * = p < 0.05; ** = p < 0.01; *** = p < 0.001

TWW1, TWW2, TWW3, TWW4= Total weight lambs weaned per ewe lambing over 2, 3 and 4 lambing opportunities, respectively.

Table 3. Least squares means (± SE) for number of lambs born and weaned over different lambing opportunities

	NLB2	NLB3	NLB4	NLW2	NLW3	NLW4
Overall mean	2.64	4.11	5.53	2.26	3.37	4.31
Birth type of ewe						
Single	2.75 ± 0.10	4.29 ± 0.14	5.65 ± 0.17	2.24 ± 0.10	3.46 ± 0.13	4.36 ± 0.18
Twin	2.79 ± 0.12	4.32 ± 0.16	5.85 ± 0.20	2.35 ± 0.11	3.60 ± 0.15	4.65 ± 0.20

NLB2, NLB3, NLB4= Number of lambs born per ewe lambing over 2, 3 and 4 lambing opportunities, respectively. NLW2, NLW3, NLW4= Number of lambs weaned per ewe lambing over 2, 3 and 4 lambing opportunities, respectively.

Table 4. Least squares means (± SE) for total weight weaned over different lambing opportunities

	TWW1	TWW2	TWW3	TWW4
Overall mean	14.55	28.11	41.17	51.79
Birth type of ewe				
Single	14.28 ± 0.67	26.88 ± 1.18	40.28 ± 1.59	49.74 ± 2.02
Twin	14.69 ± 0.77	28.72 ± 1.34	42.44 ± 1.81	53.75 ± 2.30

TWW1, TWW2, TWW3, TWW4= Total weight lambs weaned per ewe lambing over 1, 2, 3 and 4 lambing opportunities, respectively.

Table 5. Simple correlation coefficient for the different reproduction traits

Traits	TWW1	TWW2	TWW3	TWW4
TWW1	-	0.644***	0.541***	0.512***
TWW2		-	0.802***	0.719***
TWW3			-	0.882***
TWW4				-

*** = p < 0.001

TWW1, TWW2, TWW3, TWW4= Total weight lambs weaned per ewe lambing over 1, 2, 3 and 4 lambing opportunities, respectively.

The phenotypic correlations among the different reproduction traits are presented in Table 5. All simple correlations between the reproduction traits

were significantly related to each other. This is an expected because total weight weaned in the subsequent parity forms part in the calculation of total weight weaned in the following parity.

Conclusions

The regression of reproduction on ewe yearling weight was significant in all reproduction traits investigated. This may indicate that significant improvement in ewe lifetime production could be achieved by indirect selection for ewe yearling weight. The high phenotypic correlations between total weight weaned per ewe lambing over the first lambing opportunity (TWW1) and total weight weaned per ewe lambing over the latter parities could also indicate that TWW1 may be used to indirectly improve ewe lifetime production if selection is based on it.

Acknowledgments

We would like to extend our inmost gratitude to Mr. Birhan Feleke and Mr. Berhanu Soboqa for their invaluable assistance in data extraction. In the long years of this study many people have participated in the management of the flock and collection of data at one or the other stage. We are grateful to them.

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Eth. J. Anim. Prod. 6(1) - 2006: 90-95

SHORT COMMUNICATION:

A Preliminary Study on Small-Scale Fishmeal Preparation and its Effect on the Growth Performance of Chicks

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Abstract

This study examined the small-scale preparation of fish meal and evaluated its effect on the growth performance of chicks. Clean fish offal including gills, viscera, gut, gonads, skin, scale, eyes and skeleton including the head was bulked, chopped and sun dried. Although it took longer than anticipated, it was possible to naturally dehydrate fish offal in seven to ten days period. It was also possible to grind the dried fish offal with mortar and pestle. Chicks were fed on the homemade fishmeal for a period of 30 days and the substitution effect of the fishmeal to linseed was evaluated. There was a marked improvement in feeding and growth performance of chicks when the product substituted linseed meal at various levels. Feed intake improved by 170% and body weight gain by 717% with the highest (100%) level of substitution of linseed meal.

Key words: Fishmeal, linseed, growth performance, chicks

Introduction

Good nutrition is a prerequisite for a profitable poultry production and increased resistance to poultry diseases. The feed resources for chicken around Awassa town are mainly based on cereals and their by products, oil seed meals; and meat and bone meal. Recently, linseed meal has been the only protein supplement available on local markets in the area. Despite its low quality protein and a high (3-10%) content of mucilage (McDonald et al., 1981) it has been incorporated in poultry ration as the sole protein supplement.

On the other hand, Lake Awassa, which is adjacent to the town and covers an area of 91 Km^2, produces approximately 500 tons of fish annually. About 50% of this is wasted as inedible fish offal. The fish, offal if properly processed, can be converted to fishmeal, a high quality animal feed (William, 1984). The production of fishmeal commonly involves a complex mechanism

of squeezers, driers and grinders, which entails a considerable initial investment. Under the conditions of Awassa, where there is abundant sunshine almost throughout the year, it would be possible to produce fish meal at the household level following natural drying and conventional method of grinding. The integration of poultry and fishery is important in terms of improvements in production, human and animal welfare, and environmental protection. This preliminary study examined the possibility of homemade fishmeal preparation and evaluated its level of substitution for linseed meal in the daily ration of chicks.

Materials and Methods

Processing of fishmeal

Clean fish offal was collected using plastic sheets to cover the ground on which the filleting was done. The fish offal consisted of gills, viscera, gut, gonads, skin, scale, eyes, and skeleton including the head. The bulk was chopped immediately after collection and was transported to Awassa College of Agriculture. The chopped offal was spread and exposed to sun every day from 9:00 a.m. to 5:00 p.m. Drying took ten days. At least three sporadic agitations and turnings were required during the day in order to enhance dehydration. Protection against scavenger birds, cats and dogs was also necessary.

The dry fish offal was thoroughly mixed and subjected to mechanical grinding, but with little success. The skin and the scale were too elastic to pulverize. The principles of proximate analysis in digesting proteins during the determination of fibers was applied to overcome this problem (AOAC, 1980) .The skin and the scale were boiled for one hour in water into which dilute sulfuric acid solution was added at the rate of 0.005% and water was allowed to evaporate over the heat. The remaining mass was spread in the sun until it dried up. This process of drying took only two days due to the separation of some fat from the skin while boiling. The mass was then ground easily with mortar and pestle, which eventually resulted in a home made fishmeal.

Experimental rations and feeding trial

Four treatment rations were formulated to contain 20% crude protein and equal amount of basal diet. To each ration salt and limestone were added at a rate of 1%. A vitamin premix supplement was included at the rate of one gram in four kilograms of drinking water. The composition of the treatment rations

is presented in Table 1 and the rate of substitution of fishmeal to linseed meal was as follows:

Ration 1: All linseed meal	+	No fishmeal
Ration 2: Two parts linseed meal	+	One part fishmeal
Ration 3: One part linseed meal	+	Two parts fishmeal
Ration 4: No linseed	+	All fishmeal

Eighty day old Rhode Island Red chicks, purchased from the Awassa Poultry Husbandry Center, were used in the experiment after two weeks of acclimatization. The chicks were then divided, at random, into 16 equal groups. Each group of five chicks was kept in a 50 cm x 100 cm pen furnished with bedding of sawdust, feeders, waterers and 60 watt bulb hanging at an adjustable height over the chicks. The sixteen groups were further divided arbitrarily into four treatment groups each with four replications. Each group was allowed to adapt to the treatment ration for a week before actual measurement started. The feeding trial lasted for 30 days.

Table 1. Chemical composition of the experimental rations

	Maize CP		Linseed meal CP		Fish meal CP		Ration CP
	(g)	g/fresh wt.	(g)	g/fresh wt.	(g)	g/fresh wt.	%
Ration 1	320	27	255	87	--	--	20
Ration 2	320	27	170	58	30	20	20
Ration 3	320	27	80	27	60	39	20
Ration 4	320	27	--	--	85	56	20

Ration 1 = all linseed, Ration 2 = 2:1 Linseed:fishmeal; Ration 3 = 1:2 Linseed:fishmeal; Ration 4 = all fishmeal

Measured amount of feed was provided every day. The left over was collected and measured separately before the next allowance of the daily ration was supplied. Clean and fresh water was provided every morning. Body weight of each replicate was recorded at the beginning of the trial and then at weekly intervals. The feed ingredients were subjected for chemical analysis using the proximate analysis procedure (AOAC, 1980).

Results and Discussion

The chemical composition of the fish meal is presented in Table 2. It was possible to naturally dry the fish offal to a moisture content of only 8%. The protein content (70 %) of the resultant fishmeal was high. The fat content (9 %) was moderate, but the mineral content (13 %) was lower than values recorded for commercially prepared fishmeal. Good quality fishmeal contains

between 60 % and 70 % protein, 2% to greater than 14 % oils; 6% to 12% moisture, and 18% to 25% minerals (Fact sheet PS-12, 1997). Mineral levels in the range of 10% to 20% are also recorded (McDonald et al., 1981).

Table 2. Nutrient composition of the feed ingredients

	Maize	Linseed meal	Fish meal
DM (g/kg)	910	900	919
CP (g/kg DM)	87	347	760
EE (g/kg DM)	34	59	110
Ash (g/kg DM)	11	54	152
CF (g/kg DM)	15	98	--
Ca (g/kg)	0.26	36.5	55
P (g/kg)	2.38	76.5	33
Lysine (g/kg)[a]	--	--	48
Methionine (g/kg)[a]	--	--	16

[a] FIN, 2001

There was a marked ($P \leq 0.05$) improvement in dry matter intake, body weight gain and feed conversion efficiency in chicks fed with rations containing higher levels of fishmeal as a substitute for varying levels of linseed meal (Table 3). Rations 2, 3, and 4 containing ⅓, ⅔ and 3/3 of protein from fishmeal respectively supported 54%, 98% and 170 % more feed intake than the control containing only linseed meal. The trend in body weight gain was similar to feed intake but the magnitude of improvement was more intensified. Compared to the control group, there was 90%, 284% and 717% more body weight gain in the chicks fed with rations 2, 3 and 4, respectively. Such an intensified degree of difference was not expected, even if the fishmeal was believed to support a better performance due to its better quality of protein. Fishmeal is a natural, balanced animal feedstuff, rich in high quality protein, beneficial oils, vitamins and minerals. Fish oil is also rich in the health promoting long unsaturated fatty acids referred to as Omega-3S. In animals, Omega-3S are anti-inflammatory, improve fertility and reduce stress (FIN, 2001). To the contrary, linseed meal is characterized by apparently poor protein quality, and is deficient in lysine and methionine content and has low level of calcium. It also contains a considerable amount of mucilage, which collects the feed into a gummy mass around the beak reducing the bird's ability to eat (Church, 1991). Fishmeal, on the other hand, increases the Omega-3S content of the meat and eggs, and these products improve the Omega-3S status in human diet. Omega-3S in human diet prevents or reduces the chance of developing coronary heart diseases, reduces high blood pressure, kidney disorders, inflammatory bowel disorders

and autoimmune diseases. The fish oil fatty acids are also essential to the growth and development of the unborn and newborn babies and toddlers (FIN, 2001).

Table 3. Mean (x ± SE) feed intake, body weight gain and feed conversion efficiency of chicks fed the different rations

Treatments	DM intake (g/ 30 days)	Body weight gain (g/ 30 days)	Feed conversion efficiency [(BWT gain/DM intake (g/g)
Ration 1	240± 36^{a}	32 ± 7.2^{a}	0.14 ± 0.01^{a}
Ration 2	370 ± 33^{ab}	61 ± 1.8^{b}	0.17 ± 0.02^{a}
Ration 3	475 ± 48^{b}	123 ± 1.8^{c}	0.27 ± 0.02^{b}
Ration 4	650 ± 31^{c}	262 ± 2.1^{d}	0.40 ± 0.01^{c}

Means in the same column followed by different superscript letters are significantly different at *P*=0.05. Ration 1 = all linseed, Ration 2 = 2:1 Linseed:fishmeal; Ration 3 = 1:2 Linseed:fishmeal; Ration 4 = all fishmeal.

In conclusion, following the procedures given in the materials and methods, it is possible to produce homemade fishmeal. The product, when supplemented to basal diets of chicks results in considerable improvement in feed intake and growth performance. Linseed meal, on the other hand, had a performance depressing effect at all levels of substitution, and the impact worsened with increasing levels of linseed meal.

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Eth. J. Anim. Prod. 6(1) - 2006: 97-99

FEATURE ARTICLE:

Should Vaccination be Considered as a Conservation Measure for Backyard Chicken Threatened with Highly Pathogenic Avian Influenza?

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Summary

If avian flu occurs in Ethiopia, gets out of control and affects large areas of the country and domestic "backyard" chickens are exterminated en masse to contain disease spread, as is expected to happen, not only will millions of Ethiopians lose a significant part of their livelihood that will not easily be replaced, but also the entire genetic pool of these chickens, bred informally for generations, would become extinct.

Background

There is not a single conservation gene-bank, or even a safe breeding farm, producing indigenous chicken in Ethiopia. The smallholder producers themselves are the only sources of these genetic resources – be it for utilization or conservation needs. Thus, the only short-term viable option to save the indigenous chicken in Ethiopia is *in-situ* conservation.

There is very limited comprehensive information on the extent of genetic diversity, distribution and potential uses of the indigenous chicken in Ethiopia. The few comprehensive studies conducted so far affirm the widely held belief that the known breeds/ecotypes harbour substantial genetic variability that can serve current and future needs for utilization. They also have valuable specific production and adaptation traits (e.g. tolerance/resistance to diseases, capacity to thrive on low levels of nutrition and extremes of climate). Therefore, the existing breeds/ecotypes should be conserved to cater for the needs of current and future generations.

The risk

In the event of confirmed presence of the Avian Influenza virus, one of the most effective options for control of disease spread is culling (exterminating)

affected and at-risk populations, although it is still debateable whether backyard chicken would constitute a serious threat in the control of the disease. Other complementary measures include ring vaccination and movement control. Large-scale culling (stamping out) can have far-reaching and irreversible consequences if it covers the entire natural breeding tract of known or unknown indigenous breeds/ecotypes of indigenous chicken.

Other arguments

Because diseased animals are either die or continue to be sources of infection, veterinarians suggest that all infected and at-risk animals should be culled. Vaccinated animals do not contract infection, but can serve as physical carriers of the disease. Moreover, it is argued that their antibody reaction on disease diagnosis is similar to those which have the disease, making it difficult to differentiate diseased and positively reacting (vaccinated) animals.. Nevertheless, vaccines approved by OIE are known to be very potent and provide full protection. However, due to improper administration of the vaccine, very few vaccinated chicken may acquire the infection without overt clinical manifestation of illness. In addition, to differentiate infected from vaccinated flocks, the DIVA (differentiating infected from vaccinated animals) system is designed. This is effected by leaving some unvaccinated (tagged) population in vaccinated flocks. The current circulating wild virus is H5N1. The use of heterologus vaccine, e.g. H5N9 inactivated vaccine, could allow genetic and serological differentiation in the process of diagnosis of infection in vaccinated populations.

The way forward

To avoid the difficulties in differential diagnosis, administration of vaccination is suggested in clearly defined and effectively isolated (movement control) buffer zones around quarantined naïve chicken populations, leaving some control chicken flocks unvaccinated within the vaccination zones to serve as indicators of disease presence. Should the disease occur in these zones, chicken in the control flocks would die, in which case all affected and at risk chicken populations would be stamped out to control further disease spread.

If we don't vaccinate, but rather opt to exterminate backyard chickens en masse covering whole breeding tract of known or unknown breeds, the entire breed will go extinct, and the country will certainly lose the existing genetic diversity in the indigenous chicken. Lost genetic diversity in extinct

indigenous chicken breeds is irreplaceable. Learning from experiences in heavily affected countries in Asia, this scale of loss may be unlikely to happen; yet the danger is real.

It is also argued that the same logistic constraints for vaccination will apply to stamping out. Because of the small flock sizes, indigenous chicken populations will have to be head-counted in dispersed individual farmer homesteads by travelling from village to village for both stamping out and vaccination. In other words, similar organizational measures that apply for mass culling can be taken to address the presumed logistic constraints of vaccination.

As judged from the patterns of disease prevalence and spread in affected countries, the risk of contracting the Avian Influenza virus in backyard chicken flocks is not expected to be as high as for commercial flocks. There are also precedents for vaccination against Avian Influenza:

- Even China and Indonesia with their vast chicken industry are using vaccination as a prevention and control measure;
- EU has also permitted AI vaccinations "if a threatening international situation arises, without this leading to restrictions on community trade".
- On the basis of recent research, Dutch scientists recommend vaccination to halt the spread of bird flu and reduce possible human infection.
- FAO position paper on Avian Influenza of 2004 recommend vaccination of poultry for preventive and disease irradiation purposes, but on cost recovery basis.

Based on these arguments, provisions must be given for: 1) ring vaccination of back yard chicken following confirmed outbreaks inside the country, and 2) targeted vaccination of poultry in semi-intensive and intensive production settings when the disease occurrence (e.g. outbreak of HPAI in a neighbouring country or in a certain part of the country) is apparent, as one means to maintain *in situ* conservation stocks of indigenous chicken as well as parent and breeding stocks in modern farms .The alternative solution of establishing *ex situ* conservation flocks in the country would require very stringent and perhaps unattainable bio-security measures.

Information for Contributors

General

Ethiopia is one of the countries endowed with a large number and diverse livestock resources. The spectacular land formation, ranging from mountain chains with peaks of over 4500 m asl to areas below sea level, has created diverse climatic conditions with variable agro-ecological zones and rich biodiversity. This unique variability has afforded the country for the evolution and development of different agricultural production systems. Different species and breeds of livestock have been domesticated and used for various purposes. The different production systems and the economic and social roles that livestock play in the livelihood of millions of smallholder farmers is substantial. The proper exploitation of this large number and diverse livestock resource in the country has remained a great challenge to all professionals engaged in livestock production. This has also afforded a number of national and international organizations a great opportunity to undertake research and development activities to ensure proper utilisation and conservation of these resources.

In order to co-ordinate such efforts and to streamline the research and development agenda, The Ethiopian Society of Animal Production (ESAP) has been operational since its establishment in 1985. ESAP has created opportunities for professionals and associates to present and discuss research results and other relevant issues on livestock. Currently, ESAP has a large number of memberships from research, academia, and the development sector. So far, ESAP has successfully organised about 10 annual conferences and the proceedings have been published. The ESAP Newsletter also provides opportunities to communicate recent developments and advancements in livestock production, news, views and feature articles. The General Assembly of the Ethiopian Society of Animal Production (ESAP), on it's 7th Annual Conference on May 14, 1999, has resolved that an Ethiopian Journal of Animal Production (EJAP) be established. The Journal is intended to be the official organ of ESAP.

The ***Ethiopian Journal of Animal Production (EJAP)*** welcomes reports of original research data or methodology concerning all aspects of animal science. Study areas include genetics and breeding, feed resources and nutrition, animal health, farmstead structure, shelter and environment, production (growth, reproduction, lactation, etc), products (meat, milk, eggs, etc), livestock economics, livestock production and natural resources management. In addition the journal publishes short communications, critical review articles, feature articles, technical notes and correspondence as deemed necessary.

Objectives

To serve as an official organ of the Ethiopian Society of Animal Production (ESAP).

Serve as a media for publication of original research results relevant to animal production in Ethiopia and similar countries and contribute to global knowledge

To encourage and provide a forum for publication of research results to scientists, researchers and development workers in Ethiopia

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Each publication shall include some or all of the following columns.

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Research articles based on basic or applied research findings with relevance to tropical and sub-tropical livestock production.

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Short communications are open to short preliminary reports of important findings; normally not more than 2000 words. They may contain research results that are complete but characterized by a rather limited area or scope of investigation, description of new genetic materials, description of new or improved techniques including data on performance. They should contain only a few references, usually not more than five and a minimum number of illustrations (not more than one table or figure). Abstract should not be more than 50 words.

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Review papers will be welcomed. However, authors considering the submission of review papers are advised to consult the Editor-in-Chief in advance. Topical and timely short pieces, news items and view points, essays discussing critical issues can be considered for publication

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Feature articles include views and news on the different aspects of education, curricula, environment, etc will be considered for publication after consulting the Editor-in-Chief. Areas for consideration include education, society, indigenous knowledge, etc.

Technical notes
Technical notes relate to techniques and methods of investigation (field and laboratory) relevant to livestock production. Notes should be short, brief and should not exceed one page.

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Letters on topics relevant to the aims of the Journal will be considered for publication by the Editor-in-Chief, who may modify them.

Frequency of publication
Once a year (May)

Guidelines to Authors

General

The ***Ethiopian Journal of Animal Production (EJAP)*** publishes original articles of high scientific standard dealing with livestock and livestock related issues. Reviews on selected topics on livestock research and development appropriate to Ethiopia and other similar countries will also be considered for publication. Short communication and technical notes are also welcome.

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Crosse, S., Umunna, N.N., Osuji, P.O., Azage Tegegne**,** Khalili, H. and Abate Tedla. 1998. Comparative yield and nutritive value of forages from two cereal-legume based cropping systems: 2. Milk production and reproductive performance of crossbred (*Bos taurus x Bos indicus*) cows. Tropical Agriculture 75 (4):415-421.

Book

Steel, R.G.D. and Torrie, J.H. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., New York.

Chapter in a Book

Zerbini, E., Takele Gemeda, Alemu Gebre Wold and Azage Tegegne. 1995. Effect of draught work on the metabolism and reproduction of dairy cows. In: Philips, C.J.C. (ed.), Progress in Dairy Science. Chapter 8. CAB International. pp. 145-168.

Paper in Proceedings

Alemu Gebre Wold, Mengistu Alemayhu, Azage Tegegne, E. Zerbini and C. Larsen. 1998. On-farm performance of crossbred cows used as dairy-draught in Holetta area. Proceedings of the 6th National Conference of the Ethiopian Society of Animal Production (ESAP), May 14-15, 1998, Addis Ababa, Ethiopia, pp. 232-240.

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Abbreviations
Follow standard procedures.

Units
All measurements should be reported in SI units. (e.g., g, kg, m, cm)

Table 1. The following are examples of SI units for use in *EJAP*

Quantity	Application	Unit	Symbol or expression of unit
Absorption	Balance trials	Grams per day	g d^{-1}
Activity	Enzyme	Micromoles per minute per gram	µmol min^{-1} g^{-1}
Area	Land	Hectare	ha
	Carcass	Square centimetre	cm^2
Backfat	Carcass	Millimetres	Mm
Concentration	Diet	Percent	%
		Gram per kilogram	g kg^{-1}
		International unites per kilogram	IU kg^{-1}
	Blood	Milligram per 100 mL	Mg dL^{-1}
		Milliequivalents per litre	Mequiv L^{-1}
Density	Feeds	Kilogram per hectolitre	Kg hL^{-1}
Flow	Digesta	Grams per day	g d^{-1}
	Blood	Milligrams per minute	mg min^{-1}
Growth rate	Animal	Kilogram per day	Kg d^{-1}
		Grams per day	g d^{-1}
Intake	Animal	Kilograms per day	Kg d^{-1}
		Grams per day	g d^{-1}
		Grams per day per kg bodyweight$^{0.75}$	g d^{-1} $kg^{-0.75}$
Metabolic rate	Animal	Megajoules per day	MJ d^{-1}
		Watts per kg bodyweight	W kg^{-1}
Pressure	Atmosphere	Kilopascal	KPa
Temperature	Animal	Kelvin or degree Celsius	K or ^oC
Volume	Solutions	Litre	L
		Millilitre	ML
Yield	Milk production	Litres per day	L d^{-1}
Radioactivity	Metabolism	Curie or Becquerel	Ci (=37 GBq)

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