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Research Paper

Sheep supplementation in the arid and semi-arid areas of northern Kenya

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Abstract. The objective of this study was to assess the effects of partial supplementation of 1.5 years old blackhead Persian sheep with hay, molasses and local salt (Chalbi salt). The nutritive values of hay, molasses and *Chalbi* salt were determined. The selected sheep were assigned to three treatments in a completely randomized design; 10 sheep were given to the farmer and were herded based on his management practice (denoted as treatment A), 10 were grazed for 5 h and later supplemented with 600 g of chopped hay mixed with molasses per sheep daily and *Chalbi* salt *ad libitum* (denoted as treatment B), 10 were introduced to a government research farm, Kenya Agricultural and Livestock Research Organization (KALRO-Marsabit) flock and managed on the free range with no supplementation except *Chalbi* salt. They were also grazed for 8 h daily (denoted as treatment C). Feed resources for partial supplementation were analysed for proximate analysis, Van soest, *in-vitro* dry matter digestibility and mineral profiles. Molasses was spread on hay to increase palatability and intake. Chalbi salt was provided *ad libitum* to the supplemented group. All 30 sheep were weighed weekly. The data on sheep weights were analyzed using Statistical Package for Social Sciences (SPSS). The mean sheep weight over the study period was higher among the supplemented group B (25.95 kg), followed by on-station research farm-managed group C (22.60 kg) and lastly farmer-managed group A (19.50 kg). Supplementation of sheep using local feed resources enhances weight gain and this is recommended, essentially in a weight-based marketing system.

Keywords: Market, nutrients, sheep, supplement, weight.

INTRODUCTION

Sheep are a key livestock resource in the Arid and Semi-Arid Lands (ASALs) of northern Kenya, where they provide food (animal protein), besides playing an important socio-economic role to the pastoralist population (Ojango *et al*., 2018). They contribute 88% of the revenue for small holder farmers in the tropics (Kosgey *et al.*, 2003). Sheep and goats contribute 30% of the red meat (Ahuya *et al.*, 2005). Small ruminants also complement the other livestock in the utilisation of available feed reshources and provide one way of utilising the vast areas of natural vegetation where crop production is impractical. The advantages of small ruminants over large ruminants include a rapid rate of reproduction, the ability to exploit a wide range of feed resources in different ecological environments, rapid post-drought recovery, and lower watering frequency (Devendra, 2002). Changing socio-economic conditions characterised by recurrent droughts, increasing sedentarization, changes in land use patterns, inadequate feed resources especially during the dry season, rapid population growth and climate change in northern Kenya over the last few years have led to increasing food insecurity, with improving the productivity of small ruminants remaining as the major option (Groom and Western 2013). The natural vegetation found in these

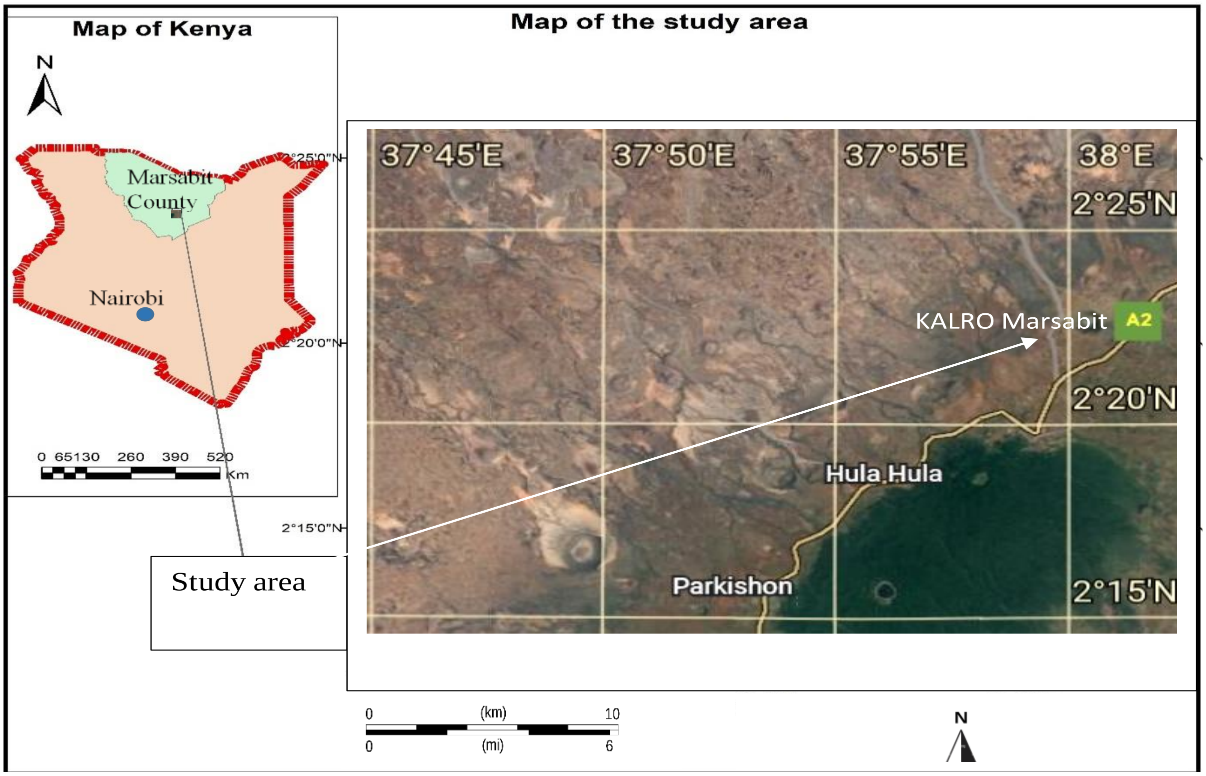

Figure 1. Study area.

areas is usually of poor quality and animals are not supplemented with concentrates except salt and/or mineral soil (Seifu, 2009). The small ruminants are kept mainly by the pastoralists, while under the mixed crop-livestock farming systems, it is the resource-poor farmers who keep mostly small ruminants. Efforts aimed at addressing constraints in feeds and feeding regimes are increasingly seen as a meaningful remedy for reducing pastoralists' vulnerability to droughts and related climate shocks. Intervention with supplementary feeding to maintain or increase production is necessary, especially with the expected increasing frequency of drought and feed scarcity. Supplementation is also crucial in weight-based sheep marketing systems and improved regional food security.

MATERIALS AND METHODS

Study area

The study was conducted in Kenya Agricultural and Livestock Research Organization (KALRO), a government research station in Marsabit County, Kenya (Figure 1). The mean annual precipitation in Marsabit county ranges between 200 and 1,000 mm per annum in the plains and foot slopes of the mountainous areas, respectively. The rainfall in the study area is distributed between two seasons, long rains from March to May and short rains occurring from October to December, with dry periods in June, July, August and September (the time when the study was conducted). Marsabit County experiences tropical climatic conditions with temperatures ranging from a minimum of 10.1°C to a maximum of 30.2°C with an annual average of 20.1°C.

Selection of experimental sheep and partial supplementation of sheep with hay, molasses and local salt (Chalbi salt)

Thirty blackhead Persian entire sheep aged 1.5 years were selected for the experiment. Before the commencement of the experiment, all the sheep were treated against ectoparasites using ectopor, triatix® and endo-parasites using Ivermectin 1% (Coopers limited). The initial live weight of the sheep was taken using an electronic weighbridge, Model name (Digital crane scale GS-C), and serial number 105007C13008. The initial live weights of the sheep ranged from 16.0 to 31. 5 kg. The selected sheep were assigned to three treatments in a completely randomized design with 10 sheep per treatment as follows:

• 10 sheep were given to the farmer who was to manage them based on his management practice (denoted as **treatment A**)
• 10 were grazed for 5 hours (from 8.00 am to 1.00 pm)

and later supplemented with 600 grams of chopped hay mixed with molasses per sheep daily and Chalbi salt *ad libitum* (denoted as **treatment B)**. This group of animals was housed in individual pens measuring 3.0 m wide and 3.5 m long and fed individually from troughs made from fabricated plastic drums. Every morning and evening, the animals were observed for any abnormalities by the herders, the field clerk and the researcher and animals having ectoparasites and showing signs of ill-health were promptly treated.

• 10 were introduced to a government research farm (KALRO-Marsabit) flock and managed on free range with no supplementation except Chalbi salt. They were also grazed for 8 hours daily (denoted as **treatment C**).

All 30 sheep were weighed weekly. Molasses was mixed in a ratio of 1:4 (1 L of molasses in 4 L of water and thoroughly spread on a 20 kg bale of hay).

Chemical analysis of hay, molasses and local salt (Chalbi salt)

The hay was sampled for proximate analysis, Van soest and *in vitro* dry matter digestibility. Molasses was sampled and analysed for proximate parameters, macro and micro minerals while Chalbi salt was analysed for macro and micro minerals. Hay samples were first oven dried at 60°C for 48 h and thereafter preserved. The hay samples were ground using a Wiley mill (Type: WRB80C/2Q). The solid particles of the Chalbi salt were ground using a mortar and pestle to a fine texture, sieved to get rid of large particles and all the two feed ingredients were stored in labelled sample bottles for laboratory analysis. The dry matter, ash and crude protein content of the feeds were determined by drying the sample in an oven set at 105°C for 12 h, ashing in a muffle furnace and the Kjeldahl procedure (AOAC, 1995). Similarly, ether extract was obtained by Soxhlet extraction method for 12 h, dried in an oven at 105°C for 30 min, cooled in a desiccator and weighed using a 0.0001g precision analytical balance (Model No. ASB-220-C2). The crude fibre was determined by boiling moisture-free and fat-free samples in dilute sulphuric acid and then in dilute potassium hydroxide, drying the residue in an oven at 105°C for 2 h followed by ashing in a muffle furnace at 600°C for 2 h, cooling and weighing. NFE was determined mathematically by subtracting the sum of percentages of all the nutrients already determined from 100 (AOAC, 1995).

Fibre fractions; Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) were determined following the sequential procedure of Van Soest *et al.* (1991). The invitro dry matter digestibility of the hay samples was determined using the two-stage technique for the digestion of forage samples (Tilley and Terry, 1963).

Macro-elements (Mg, Ca) and trace elements (Cobalt, Copper, Zinc, Iron and Manganese) were determined using Buck scientific atomic absorption spectrophotometer (Model-BUCK210) following the procedure of AOAC (1998). Potassium and Sodium were determined by the use of a flame photometer (model-JENWAY). Phosphorus was determined by use of a UV-Visible spectrophotometer (HITACHI 2900, Model No. 2JI-0003) (AOAC, 1998).

Gross margin analysis

A Gross Margin Analysis (GMA) and Cost Benefit Ratio (CBR) of combining grass hay mixed with molasses and Chalbi salt were done to ascertain the viability of the partial supplementation.

The gross margin was obtained by subtracting the total variable cost of all the inputs from the benefit/income from sheep sales. The BCR was obtained by taking the benefits/income gained from sheep sales versus the costs incurred in supplementing the sheep.

Data analysis

The data on sheep weights were analyzed using SPSS version 26 software, analysis of variance (ANOVA) procedures in a completely randomized design (CRD). The treatment means were separated using the least significance difference (LSD) at 5%.

RESULTS AND DISCUSSION

Partial supplementation of sheep with hay, molasses and local salt (Chalbi salt)

Nutritional composition of hay, molasses and local salt (Chalbi salt)

The proximate composition, VanSoest analysis and *In-Vitro* Dry Matter Digestibility (IVDMD) of hay and molasses are presented in Tables 1 and 2. There were differences in proximate composition and mineral profiles between these two feed resources. Hay and molasses had an overall mean crude protein (CP) content of 3.63 % and 2.60 %, respectively. Hay had a higher Dry Matter (DM) and CP content compared to molasses. However, molasses had higher Nitrogen Free Extracts (NFE) /soluble carbohydrates compared to hay. The high dry matter content in hay could be attributed to conservation processes in hay-making where moisture is completely removed in the hay by drying for 3 days after harvesting and during the baling process, the air is completely removed from the feed material by thoroughly pressing the feed materials. Molasses on the other hand has more moisture in nature which translates to low dry matter content. The mean CP content of 3.63 % and 2.60 % in

Table 1. Proximate composition, Vansoest and *in vitro* dry matter digestibility of grass hay.

Sample description	DM%	ASH%	CP%	CF%	EE%	NFE%	%NDF	%ADF	%ADL	%IVDMD
Hay 1	96.1	11.73	3.93	33.65	0.74	49.95	68.85	41.54	8.06	43.07
Hay 2	96.8	10.87	3.54	34.8	0.98	49.81	71.20	46.72	9.66	42.36
Hay 3	96.14	10.38	3.41	37.34	0.6	48.23	74.56	46.04	8.15	39.93
Mean	96.35	10.99	3.63	35.26	0.77	49.33	71.54	44.77	8.62	41.79

Key: DM: Dry Matter**, ASH:** Ash**, CP:** Crude Protein**, CF:** Crude Fibre**, EE:** Ether Extract (Crude Lipids)**, NFE:** Nitrogen Free Extract (Soluble carbohydrates), **NDF:** Neutral Detergent Fibre, **ADF:** Acid Detergent Fibre, **ADL**: Acid Detergent Lignin, **IVDMD**: Invitro Dry Matter Digestibility

Table 2. Proximate composition and mineral profile of molasses.

Sample description	DM%	ASH%	CP%	CF%	EE%	NFE%	%Na	%K	%Mg	%Ca	%Fe
Molasses 1	69.86	6.71	2.62	0.21	0.17	90.29	0.42	1.46	0.08	0.16	0.078
Molasses 2	70.45	6.66	2.41	0.19	0.6	90.14	0.48	1.31	0.07	0.17	0.07
Molasses 3	70.08	6.48	2.77	0.16	0.34	90.25	0.44	1.69	0.078	0.16	0.076
Mean	70.13	6.62	2.60	0.19	0.37	90.23	0.45	1.49	0.076	0.16	0.075

Table 3. Mineral profiles in Chalbi salt.

Sample description	%Na	%K	%Mg	%Ca	%P	%Fe	%Zn	%Mn	%Cu	%Co
Chalbi salt 1	1.24	0.10	0.026	0.02	3.90	0.13	0.003	ND	ND	ND
Chalbi salt 2	1.27	0.10	0.02	0.01	3.78	0.08	0.005	ND	ND	ND
Chalbi salt 3	1.21	0.09	0.024	0.009	3.63	0.07	0.002	ND	ND	ND
Mean	1.24	0.097	0.023	0.013	3.77	0.093	0.003			

NB: National Research Council (NRC) 1981 recommended levels in sheep diet are **P** 1.6 g kg^{-1} DM, **K** 5.0 g kg^{-1} DM, **Ca** 2.0 g kg^{-1} DM, **Mg** 1.2 g kg^{-1} DM, **Na** 0.9 g kg^{-1} DM, **Fe** 30.0-50.0 mg kg^{-1} DM, **Zn** 20.0-33.0 mg kg^{-1} DM and **Mn** 20.0-40.0 mg kg^{-1} DM
Other sources: Grace (1994), Kessler (1991), Haenlein (1980) and NRC (1985)
ND means Not Detected.

hay and molasses respectively was lower than the critical level of 7.00 % for temperate forages (McDowell, L.R 2003) and 6.00% for tropical forages (Minson, 1990) below which the feed intake of the animal is compromised. The high dry matter content observed in the hay was attributed to the sampling of the grasses for analysis when they were fully dried compared to molasses that contained a lot of moisture. The mean structural constituents (NDF, ADF and ADL) content of hay was 71.54, 44.77 and 8.62%, respectively (Table 1). The increase in structural constituents could have been due to seasonal effect as feeding and sampling were done during the dry season. The seasonal effect agrees with Abdullah *et al*. (2017), who reported that detergent fibres of a plant may vary depending on the time and season of the year when they are harvested. Hay had a low CP of 3.63% and a low IVDMD of 41.79%. This observation is in agreement with the current study as plants low in CP content were also low in IVDMD.

Molasses had high concentrations of sodium and potassium while Chalbi salt had a high concentration of Na, P, Fe and Zn (Tables 2 and 3). The Ca content of Chalbi salt of 0.13 g kg^{-1} (0.013%) was lower than the Ca content of 3.0 g kg^{-1} reported by Kuria, (2004). Whilst the zinc content of 0.003% (30 mg kg^{-1}) in Chalbi salt in this study was higher than the zinc content of 29.0 mg kg^{-1} reported in Chalbi salt by Kuria, (2004) in Kenya. Inadequate Zn levels have been associated with impaired reproductive functions (Underwood and Suttle, 1999), hence the need to supplement grazing sheep. The high iron content in Chalbi salt could be a result of variations in edaphic factors. Iron deficiency in adult sheep is rare as their requirements are met or even exceeded through soil ingested on pasture (Underwood, 1981). Other studies have shown that most Kenyan grazing sheep have adequate levels of Fe, derived directly from pasture or by ingesting soil along with grass (French, 1955). Both soil and pasture forage levels of Fe are considered adequate (Jumba, 1989). The low levels of Mg and Ca (below the recommended levels in the diet) in both molasses and Chalbi salt is most likely to have a negative effect on the weight gain of sheep. This is because they are associated with energy metabolism, therefore, their deficiencies may reduce meat production. Generally, the disparities in the concentrations of macro and micro-minerals among the studied feed resources could be contributed to the nature

Table 4. Weekly live body weight (kg) of all experimental sheep.

Treatment	WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9	WK10	WK11	WK12
HMC	25.55[a]	25.95[a]	26.25[a]	27.25[a]	27.30[a]	27.50[a]	28.00[a]	28.05[a]	27.70[a]	25.95[a]	26.85[a]	25.95[a]
KM	25.50[a]	23.55[ab]	23.95[a]	23.90[ab]	24.90[a]	24.40[ab]	24.80[ab]	23.90[b]	23.20[b]	23.65[b]	23.30[b]	22.60[b]
FM	23.35[a]	22.20[b]	23.65[a]	23.20[b]	24.85[a]	22.10[b]	21.60[b]	20.70[b]	23.15[b]	20.60[b]	20.30[b]	19.50[c]
Mean	24.80	23.90	24.62	24.78	25.68	24.67	24.80	24.22	24.68	24.07	23.48	22.68
SE	0.985	0.980	0.923	0.982	1.141	1.144	1.150	1.162	0.978	0.979	1.010	0.854
CV%	12.6	13.0	11.9	12.5	14.0	14.7	14.7	15.2	12.5	12.9	13.6	11.9
P value	0.215	0.036	0.112	0.016	0.240	0.009	0.002	<0.001	0.003	<0.001	<0.001	<0.001

Key: WK = Week, **HMC** = Hay, Molasses and Chalbi salt supplemented Group B, **KM** = KALRO Managed Group C, **FM** = Farmer Managed Group A

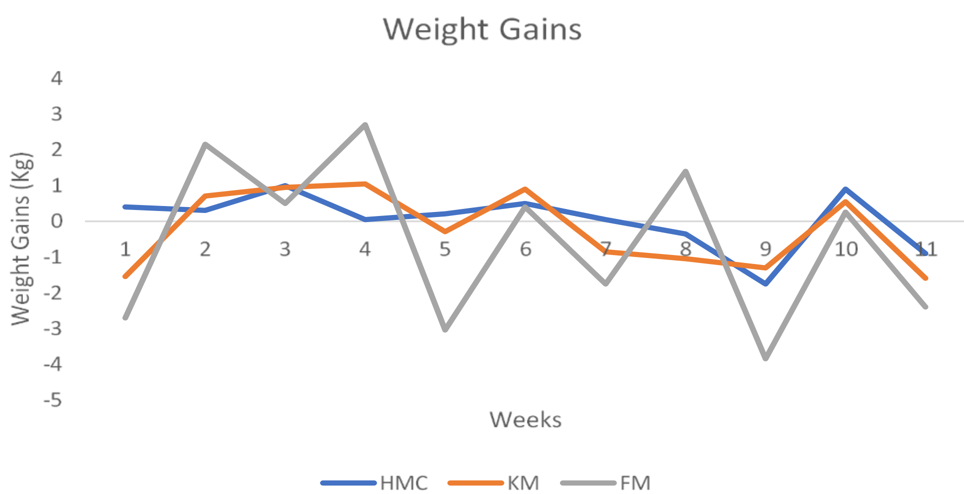

Figure 2. Weight gains of experimental sheep. **HMC**=Hay, Molasses and Chalbi salt supplemented Group B, **KM**=KALRO Managed Group C, **FM**=Farmer Managed Group A.

of the soils, the mineral status of the soil and the stage of maturity of the hay (Minson, 1990; Endalew *et al.*, 2014).

Determination of weight gain of thirty blackhead Persian entire experimental sheep

The average weekly weights for the different experimental groups are shown in Table 4. Group B and C animals had their peak mean weekly weight in week 7 while group A showed a decline. The decline in the weight of treatment A could be attributed to a change in the management practices of the farmer as the sheep had to adapt to new feeds and feeding regimes done by the farmer. Weight gains in supplemented animals are normally realized after a few weeks after the animals have attained their compensatory growth and this was the case with supplemented group B animals in week 10 and week 11. The overall superior performance exhibited by the partially supplemented group B sheep can be largely attributed to the high dry matter, digestibility and mineral content provided by hay, molasses and Chalbi salt, which enhanced weight gains. Animals raised on free range at the research farm performed better than those on farmer-managed farms and this was attributed to the high management practices employed by the research farm. The enhanced weight gain in group B sheep was in line with the findings of Getahun (2022), who reported that sheep supplemented with hay and crop residues are likely to fatten and add weight. Group B sheep had a mean monthly weight of 25.95 kg compared to 19.50 kg of group A sheep during week 12 of supplementation translating to a weight difference of 6.45 kg in 90 days. This weight was comparable to an average daily weight gain of 69.59 g/kg reported by Hassen and Ali (2019) on sheep supplemented by mixed concentrate and 15% molasses inclusion.

Farmer-managed sheep recorded the highest weight gain during weeks 2, 4 and 8 and lost weight during weeks 5 and 9 as shown in Figure 2. These fluctuations in weight gain could be attributed to management practices in the pastoral areas where pastoralists feed different feed resources to the animals irrespective of the nutritional quality, especially during the dry season. According to findings by Nantoumé (2020), poor-quality feeds are the main constraints of sheep farming. The supplemented

Table 5. Body weight changes (in kg) of experimental sheep after 90 days.

Treatment	Weight gain/loss (kg)
HMC	1.3[a]
KM	-2.2[b]
FM	-3.05[c]
P value	<0.001

HMC = Hay, Molasses and Chalbi salt supplemented Group B, **KM** = KALRO Managed Group C, **FM** = Farmer Managed Group A

group showed high gains during week 10 with KALRO managed showing a high gain in week 4. All the 3 experimental groups recorded weight loss during week 12. This period coincided with the peak dry spell in Marsabit county resulting in loss of body condition in livestock. This is because the seasonal fluctuation of feed resources follows the pattern of vegetation growth that is modified by the availability of rainfall (Nantoumé, 2020).

All the supplemented sheep (HMC) improved their body condition as indicated by their daily weight gains of 14.44 g/day (1.3 kg/90 days), while KALRO-managed (KM) and farmer-managed (FM) sheep lost 24 g/day (-2.2 kg/90 days) and 33.8 g/day (-3.05/90 days), respectively (Table 5). The weight gain of the supplemented group was lower than the weight gain of 3.49 kg reported by Tsegahun *et al*., (2006) in Ethiopia where sheep were supplemented with 100 g/day of *Lotus corniculatus* hay in addition to 8 h of grazing. KALRO-managed (KM) and farmer-managed (FM) sheep lost their weight due to drought and scarcity of feeds. The body condition of livestock reared under the pastoral system is significantly affected by seasonal fluctuations in forage availability in ASALs (Dabasso *et al.*, 2018). Therefore, the supplementary feed is expected to cater to these deficiencies.

Gross margin determination on the use of hay, molasses and Chalbi salt in partial supplementation of sheep

Processing of the feed supplements

I. Chopping of mixed grass hay

Mixed grass hay was chopped using a twin-engine portable grinder into small pieces and stored in gunny bags in a cool and dry storage shed. Chopping of mixed grass hay was done by one person working 5 h for 30 days.

Chopping of the hay was carried out from 9.00 am to 2.00 pm (5 h) by 1 person for a period of 30 days. Thus, the total time used in chopping the hay was 150 h (30 days × 5 h × 1 person). The casual rate adopted was Kenya Shillings (Ksh) 452.40 (3.60 USD) per day (8 working hours). Therefore, the cost for one hour was Ksh 56.55 thus the total cost for processing the supplement was Ksh 8,482.50 (150 h × Ksh 56.55).

II. Grinding of Chalbi salt granules

Local salt (Chalbi salt) is a natural mineral source found in the Chalbi desert of Marsabit County, Kenya, and is naturally accessed by grazing animals. Chalbi salt was bought from Marsabit town where it is sold after being scooped from the Chalbi desert in Marsabit, northern Kenya. The solid particles of the salt were ground using a mortar and pestle to a fine texture and stored in gunny bags in a cool and dry shed. Grinding large flakes of the Chalbi salt with a pestle and mortar took one hour. Large flakes of Chalbi salt were ground with a pestle and mortar in 1 hour at Ksh 56.55.

III. Utilization of Chalbi salt

Sheep were watered at an interval of 3 days, equivalent to 10 watering times in a month. Thus, during the study period, sheep were watered 30 times (90/3 days). Sheep only consumed the Chalbi salt during watering days. Each sheep was supplemented with 14 g of Chalbi salt only during watering times. In one month, 10 sheep consumed 1.4 kg of salt (14 g × 10 sheep × 10 watering times = 1400 g or 1.4 kg). The quantity of salt consumed for 3 months was 4.2 kg (1.4 kg × 3 months). The cost of 1 kg of Chalbi was Ksh 100, thus 4.2 kg of Chalbi salt cost Ksh 420.

IV. Purchase and transportation of mixed hay grass and molasses

Purchase of 27 bales of mixed grass hay from one cutting for sheep in treatment B only cost Ksh 10,800 (Ksh 400 per bale). Transportation of mixed grass hay cost was Ksh 170 (1 L of fuel runs for 5 km, and hay was bought in Marsabit town which is a 3 km journey).

V. Dilution of molasses with water and feeding of hay

Daily preparation of feeds for 10 sheep took place every morning from 12.00 pm to 1.00 pm (1 h) for a period of 90 days by 1 person. Thus, the total time used in feeding the sheep was 90 h (1-h daily × 90 days × 1 person). Therefore, the cost of feeding 10 sheep was Ksh 5,089.50 (90 h × Ksh 56.55). (Table 6)

Income from the sale of sheep by on-station auction

The income realized from the sale of partially supplemented sheep was Ksh 31,140 (248.23 US$ equivalent) while that realized from the farmer-managed sheep was Ksh 23,400 (186.53 US$ equivalent). A farmer

Table 6. Total variable costs of supplementing the sheep.

Unit	Quantity	Amount (Ksh)
Cost of Chalbi salt	10 sheep × 10 times × 14 g of salt × 100ksh/kg × 1 group/treatment (PSS)	420
Labour cost of Chalbi salt grinding		57
Cost of purchasing Mixed grass hay	27 bales × Ksh 400 per bale	10,800
Transportation costs of grass hay		170
Chopping costs of grass hay		8,482.50
Labour costs of feeding supplements	90 h × Ksh 56.55/h	5,089.50
Total		25,019.00

Ksh 125.45 was equivalent to one US$ during the study period

Table 7. Summary of gross margin and benefit cost ratio.

Item	Amount (Ksh)
Benefits (sheep sales)	31,140.00
Variable Costs	25,019.00
Gross Margin	6,121
Benefit Cost Ratio	1.24

can make up to Ksh 7,740 (61.7 US$ equivalent) more profit with partial supplementation (Table 7). There are 77,495 households in Marsabit County, out of these, 36,289 are urban and peri-urban dwellers and 41,202 pastoral and agro-pastoral households (KPHC, 2019).

According to the Marsabit County Livestock Annual Report (2022), Marsabit County had a population of 663,508 sheep. This translates to about 16 sheep per household. Supplementing the 16 sheep, a farmer can earn Ksh 49,824 in 90 days. Since livestock production contributes 82 percent and 60 percent to cash income in the pastoral and agro-pastoral livelihood zones respectively, the livelihood of farmers can be improved. The sale of sheep and goats remained the leading source of income. Sales rates are highest in sheep at 1.45% while that of goat was 1.31% (NDMA 2015 Bulletin). Therefore, partial supplementation of sheep especially during the dry season can boost the income of sheep producers in northern Kenya.

CONCLUSION

Supplementing grazing sheep with mixed grass hay, molasses and Chalbi salt enhanced weight gain. This supplementation of sheep is profitable and needs to be up-scaled amongst pastoral and agro-pastoral communities of arid and semi-arid northern Kenya. This is more so important in face of climate change and feed scarcities.

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