EFFECTS OF FEEDING SYSTEM ON PERFORMANCE OF FINISHING ANKOLE CATTLE AND MUBENDE GOATS

BY

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DECLARATION

I hereby declare that the work presented in this thesis is original and has not been submitted to any other University.

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ABSTRACT

Meat production in Uganda relies grossly on the local animal genotypes raised under extensive production systems. The productivity of the animals varies widely with changes in pasture quantity and quality in different seasons. In an effort to improve productivity, two studies were conducted to evaluate genotype and feeding system effects on the performance of the indigenous animals (i.e. Ankole cattle and Mubende goats) and their respective crossbreds. Study I evaluated effects of feeding system on performance of Ankole cattle and its crossbreds with Boran and Friesian, while study II evaluated growth and slaughter characteristics of grazing Mubende and Mubende x Boer goats supplemented with concentrates.

In study I, one hundred forty four bulls comprising 48 purebred Ankole (ANK), 48 Ankole-Boran (AXB) crossbreds and 48 Ankole-Friesian (AXF) crossbreds were each assigned to three feeding systems (FS). The bulls, average 18 months in age had initial weights of 182.3 ± 27 , 205.9 ± 26 and 188 ± 22 kg for ANK, AXB and AXF, respectively. Bulls were stratified by weight and randomly allocated within strata to a 3 X 3 factorial treatment structure. Feeding systems comprised: T1 (Grazing alone), T2 (Grazing + overnight concentrate supplementation) and T3 (feedlot finishing with ad libitum maize stover and concentrate which accounted for 60% of daily estimated feed intake). After 120 days of feeding, 8 out of 16 bulls per treatment were selected by weight for slaughter. Data collected was analysed using the general linear model procedures of SAS, 2003. Genotype and feeding system affected (P < 0.05) DM intake, growth and slaughter characteristics. Feed efficiency was 6.5, 7.1 and 7.3 for AXF, ANK and AXB, respectively, at the feedlot. Among blood metabolites measured, plasma glucose (P < 0.01) and lactate (P < 0.01) were affected by genotype while feeding system affected glucose (P < 0.05), lactate (P < 0.05), albumin (P < 0.01) and BUN (P < 0.01). Highest glucose level (i.e., 7.5 mmol/L) was observed in grazing AXB, although glucose levels generally ranged between 5.1 and 5.9 mmol/L. Lactate levels ranged between 9.6 and 13.8 mmol/L, the levels were higher in T1 than T2 which was also higher than T3 in all genotypes. Blood urea nitrogen (BUN) was higher in T3 than T2 and T1, in that order except in AXF where lowest BUN was observed in T2. Data on rumen fermentation characteristics showed that rumen pH (P < 0.05), propionate (P < 0.001), isobutyrate (P < 0.01), isovalerate and valerate (P < 0.01) varied between genotypes. Feeding system affected rumen pH (P < 0.05), acetate (P < 0.01), propionate (P < 0.001) and acetate:propionate ratio (P < 0.01). Growth rates were affected by both genotype (P < 0.01) and feeding system (P < 0.001). Average daily gains were; 0.93, 0.80 and 0.75 kg live weight gain per day for AXF, ANK and AXB, respectively, at the feedlot. Feedlot finishing (T3) also resulted in heavier carcass and non-carcass components than T2 and T1. Hot carcass weights were; 134.4,

134.7 and 138.1 kg for ANK, AXB and AXF, respectively, at the feedlot. Hot carcass dressing percentages were; 52.3, 51.8 and 51.8 % at the feedlot and 50.0, 53.1 and 50.1 % in supplementation of grazing (T2) for ANK, AXB and AXF, respectively.

In study II, 96 castrate goats (48 pure Mubende (MDE) and 48 Mubende-Boer crossbreds (MXB)) were randomly allocated to three dietary treatments in a 2x3 factorial treatment structure. The dietary treatments were: GZ (solely grazing as control), MCC (grazing animals supplemented with concentrate without molasses) and MCM (grazing animals supplemented with concentrate containing molasses). Ten out of the 16 goats per treatment were randomly selected and slaughtered after 90 days of feeding. Concentrate DM intake and feed efficiency varied between genotype (P < 0.001) and dietary treatment (P < 0.001). Concentrate dry matter (DM) intake was higher in crossbreds in MCC diet. Intake was 1.4 kg DM/animal/day and 1.6 kg DM/animal/day for pure Mubende and the crossbreds, respectively. Efficiency of MCC concentrate utilisation was 27.6 and 19.9 for MDE and MXB, respectively. Feed efficiency of MCM was 22.5 and 25.7 for MDE and MXB, respectively. Cost of supplementation per animal per day was higher in the crossbreds than the pure Mubende. There were no genotype and dietary treatment effects on most blood metabolites measured except albumin (P < 0.001) and BUN (P < 0.001). Genotype affected hot carcass weight (P < 0.001) but did not affect dressing percentage. However, dietary treatment affected both hot carcass weight (P < 0.001) and hot carcass dressing percentage (P < 0.001). Carcass weights were higher in MXB (GZ=19.2, MCC=23.0 and MCM=21.7 kg) than in MDE (GZ=17.4, MCC=20.9 and MCM=20.8 kg). Dietary treatment affected (P < 0.05) all non-carcass components except head, skin plus feet and tail, heart, kidney, empty intestines and empty stomach.

These results provide evidence that under improved feeding management, the growth rate and meat yielding potential of the Ankole cattle are comparable to their Boran and Friesian crossbreds. Further evidence also suggests that feedlot finishing offers a better opportunity to increased growth rates and meat yield compared to supplementation of grazing. A higher meat yielding potential of the Mubende goat and its Boer crossbred under improved finishing was also demonstrated.

DEDICATION

I fully dedicate my efforts in this work to my Late Father Mr. Izama Inini Tito and my Mother Holda Bako.

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ABBREVIATIONS AND ACRONYMS

- FAO: Food and Agricultural Organisation of the United Nations
- GDP: Gross Domestic Product
- IAEA: International Atomic Energy Agency
- MAFRI: Manitoba Agriculture, Food and Rural Initiatives
- NALPIP: National Livestock Productivity Improvement Project
- PPA : Participatory Poverty Assessment
- PEAP: Poverty Eradication Action Plan
- SSA: Sub-Saharan Africa
- UBOS: Uganda Bureau of Statistics

1.0 GENERAL INTRODUCTION

1.1 Background

In Sub-Saharan Africa (SSA), achieving the expended output necessary to meet prospective demand for foods of animal origin is still a daunting challenge. This has been attributed to the ever increasing human population, urbanisation and growth in income in the region (Parthasarathy *et al.*, 2005). The consumption of especially, meat and milk in SSA are still very low, estimated at 10.4 and 31.8 kg per capita, respectively, compared to the global averages of 39.7 kg for meat and 97.6 kg for milk (projections from FAO, 2007). Moreover, the demand for meat and milk is projected to increase by 97% and 100%, respectively, (Parthasarathy *et al.*, 2005) by the year 2020. These increases in demand are expected to exert considerable pressure on the livestock industry of the different countries in SSA where livestock production is still characterised by low producing indigenous animals and grazing based on extensive production systems.

In Uganda, consumption of meat and milk is estimated at 10.2 kg and 24.3 kg, respectively (FAOSTAT, 2010). These figures are noticeably below the SSA and global averages. Being one of the countries with the highest population growth rates in SSA, the low consumption rates are exacerbated by faster increase in demand for the animal products. Furthermore, the contribution of livestock to the total gross domestic product (GDP) and agricultural GDP of Uganda has continued to decline. Traditionally, livestock is said to account for about 20% of total agricultural GDP but has declined to about 17% due to insecurity, insurgency, cattle rustling and overall low productivity of the extensive systems of production (George, 1998; ADF, 2002). It is also estimated that over 90% of meat consumed in Uganda comes from the smallholder subsistence farmers practising traditional communal grazing systems (MAAIF, 1997). The bulk of the animals utilize permanent pasture especially in the rangelands which cover an estimated 84,000 km², or 43% of Uganda's total land area (Mugerwa, 2001). Virtually all the permanent pasture areas are not improved and therefore, the animals depend on natural forages and browses, which vary widely in quantity and quality throughout the year. While ample herbaceous feed of good quality is available during the rainy season, it is inadequate in both quantity and quality during the dry season (Mugerwa, 2001).

Currently the traditional communal grazing system in the rangelands in Uganda is under excessive pressure from the increasing human population. Arable cropping is said to be expanding and grazing areas consequently decreasing. Subsequently, these have negative implications on the supply of feeds and level of livestock productivity. Further still, Uganda's rangelands are also noted to be highly degraded (Mpairwe *et al.*, 2008). Overgrazing and tree harvesting for charcoal are exposing the rangelands to agents of soil erosion such as running water with subsequent severe effects on the quantity and quality of both herbage and water (Zziwa *et al.*, 2008). The overall result is therefore, a decreasing quantity and quality of livestock products with direct consequence of reduced revenue from the livestock industry, especially meat which is the most heavily dependent on the extensive production system.

Further still, the indigenous cattle which include the Ankole, East African Short Horn Zebu and Nganda account for 93.6% of the 11.4 million cattle in the country. Meanwhile, indigenous goats (i.e. Mubende, Small East African goat and Kigezi) constitute 98.7% of the 12.5 million goats (UBOS, 2009). The Ankole cattle and the Mubende goat which are the larger genotypes with highest potential for meat production of all the local breeds account for the lowest proportion of the local genotypes. The two genotypes comprise 30% and 14.5% of the indigenous cattle and goat genotypes, respectively. These genotypes have remained victims of the general perception about tropical animal genotypes that they are under performers for milk and meat production. Recent investigations have, however, proved that these animals have a higher inherent potential for meat production (Kabi, 1996, 2003; Mpairwe *et al.*, 2003). Related to these studies is also the success achieved in the South African beef industry through use of the indigenous Nguni cattle for beef production (Strydom, 2008; Strydom *et al.*, 2008). It can therefore, be argued that, a change in livestock production of quality and profitable meat in Uganda.

1.2 Problem statement and Justification

Extensive production systems and the uncharacterised indigenous animal genotypes still dominate in Uganda's meat industry. This has kept meat production a less viable enterprise. The meat yields and the economic returns from meat animals and the production systems are still invisible both at farm and the national levels. Culled animals dominate as the major source of

meat with very low quality attributes. Further still, average meat yield per animal of 150 kg for cattle in Uganda is far below the global average of 204 kg although the average meat yield per goat of 12 kg compares well with the global average of 12 kg (Parthasarathy *et al.*, 2005). Off-take rates have also remained low and stagnant between 10% and 12% (FAO, 2006).

Efforts to reverse the trends of low productivity of the meat industry in Uganda have included crossbreeding with reported improvements in performance of animals. In cattle, Gregory *et al.* (1985) observed improvements in birth weight, weaning weight and post-weaning growth rates on crossbreeding the Ankole and Zebu cattle with Boran, Red Poll and Angus breeds. While in goats, improvements in birth weight, weight at weaning and growth rates were reported by Ssewannyana *et al.* (2004) on crossbreeding the Mubende and Teso goats with the Boer. However, Gregory *et al.* (1985) concluded that adaptation to the local environment was the major factor limiting the expected improved performance from crossbred genotypes. Rege (1998) argued that utilization of locally available but adapted genotypes in combination with improvements in the environment is feasible and economical. However, the author added that considering development of appropriate breeding programmes for further improvement of the indigenous breeds may be a better option to crossbreeding. This, therefore, implies that crossbreeding alone may not be the solution to the downturn in Uganda's meat industry but also establishing the potential in the local animal genotypes may enhance meat productivity.

Meanwhile, feedlot finishing and grazing based supplementation with concentrates which have direct positive implications on increased meat yield are not also practiced in Uganda. Many farmers are not aware about these feeding practices, although, their underlying potential for improved feed utilisation and animal performance are well established (Eltarhir *et al.*, 2000; Salim *et al.*, 2003; Sebsibe *et al.*, 2007; Solomon *et al.*, 2008; Jerez-Timaure and Huerta-Leidenz, 2009). In cattle, Eltarhir *et al.* (2000a) reported daily weight gain of up to 1.13 kg in feedlot finished indigenous Western Baggara bulls in Sudan. Carcass weight of up to 216.8 kg of 20 months old indigenous Baggara bulls under feedlot finishing has also been reported (Eltarhir *et al.* (2000b). In Uganda, growth rates of up to 800 g/day of steers from maize stover and molasses basal diets in feedlot have been reported (Kabi, 2003). Solomon *et al.* (2008) reported higher dry matter intake, apparent digestibility and daily liveweight gain (65.3 g/day) in supplemented Sidama goats in Ethiopia. Similar findings were also reported by Mushi *et al.*

(2009a) on carcass and non-carcass characteristics of Small East African goats and their crossbreds with Nowegian in Tanazania. Much as this information provides evidence that intensive feeding management offer an opportunity for improved meat production, there is still a missing link in Uganda to successfully guide farmers and the country towards a profitable meat industry.

1.3 Objectives of the study

The major objective of this study was therefore to establish the productivity in terms of meat quantity and quality of the indigenous Ankole cattle and Mubende goat breeds and their respective crossbreds as influenced by feeding management. The specific objectives of were to:

- i. Assess the influence of genotype and feeding system on dry matter intake, efficiency of feed utilisation, rumen fermentation characteristics and blood metabolites.
- ii. Establish genotype and feeding system effects on growth and slaughter characteristics.
- iii. Determine the gross margins of the different genotypes under the different feeding systems.

1.4 Hypotheses

It was therefore hypothesised that:

- i. Performance of indigenous animal genotypes does not differ from their crossbreds under different feeding systems.
- ii. Feedlot finished animals perform better than grazing and concentrate supplemented animals.
- iii. Feedlot finishing and supplementation of grazing result in higher gross margins for meat production compared to sole grazing

2.0 GENERAL LITERATURE

2.1 Meat production in Uganda and opportunities for improvement

Uganda's human population of 29.6 million people is growing at a rate of 3.2 % per year (UBOS, 2008). This causes the Country to suffer a severe deficit in supply of meat to meet the demands of the ever increasing population. Much as the populations of cattle, goat, sheep, pig and chicken has been estimated to be 11.4, 12.5, 3.4, 3.2 and 37.4 million, respectively (UBOS, 2009); their rates of meat production have failed to match with the human population demands. Per capita meat consumption in Uganda is estimated at about 10.4 kg/person/year (FAOSTAT, 2010), giving a daily per capita consumption of only about 30 grams of meat per day.

A number of factors limit the supply of meat in Uganda's livestock production systems. Apart from livestock being mainly kept by smallholder farmers who are largely subsistent, productivity of individual animals is hampered by low input use, ever fluctuating quality and quantity of natural pastures on which the animals largely depend. Internal and external parasites, endemic diseases, higher temperatures and greatest of all a decreasing amount of available land also affect livestock productivity. Much as government owned ranches for beef production had been established in early 1960s, civil strife led to their collapse and to date, they have remained non-viable. Efforts by individual farmers to commercialise ranching have also not yielded fruits mainly due to limited access to inputs and lack of technical information to guide profitable extensive meat production.

Subsequently, the indigenous cattle and goat breeds which have been part of the livestock keeping communities for ages die in large numbers due to drought and feed scarcity especially at early stages of life. ICRA (1995) identified feed insufficiency and water scarcity as the major constraints to livestock production in Uganda; however, other reports show that much as water may not be evenly distributed in the Country, its sources are adequate to support livestock production. Crop residues are also widely produced and could as well cover for feed deficiencies if well managed (Mbuza and Kajura, 2000). Agro-industrial by-products which have commendable potential for improving animal performance have as well remained untapped in Uganda. Promising results have been reported regarding the utilisation of these by-products for

more productive goat and cattle feeding in Uganda (Okello *et al.*, 1994; Mpairwe *et al.* 2003; Kabi, 2003; Oluka *et al.*, 2004). Meanwhile, successful beef production systems have been established based on agro-industrial by-products and crop residues elsewhere (Preston *et al.*, 1969; Creek, 1972; Cungen and Longworth; 1998; Baset *et al.*, 2003). This, therefore, implies that an open opportunity remains in Uganda to improve on its livestock production systems if these products are put to efficient use.

Attempts to improve overall agricultural productivity in Uganda have continued to be priority for livelihood improvement. In 2000, the government initiated the Plan for Modernisation of Agriculture (PMA) with the overall objective of eradicating poverty, ensuring food security and creation of gainful employment. These objectives were to be achieved through sustainable management of the Country's natural resources through use of more productive technologies for livestock and crop farming (MFPED, 2000). Specific to meat production, the meat master plan was prepared within the PMA. The key component of the meat master plan was to improve meat production through performance testing and use of locally available feed resources under intensive management systems (MAAIF, 1998). The National Livestock Productivity Improvement Project (NALPIP) was then also developed from the Meat Master Plan. The projected outputs of NALPIP included increased livestock ownership in poor rural households and redistribution of livestock in the cattle corridor, improved livestock health and increased water supply for livestock. Other projected outputs included enhanced livestock marketing facilities and market information and generation of livestock inventory and range information (ADB, 2005). However, the impact of these programmes is yet to be realised in the meat industry.

2.2 Cattle and goat keeping in Uganda

Cattle and goats are major parts of the livelihoods of different communities in Uganda. The 2009 livestock census report (UBOS, 2009) showed that more than a quarter (26.1%) of the households in Uganda own cattle. The ownership was reported as high as 56.3% of the households in some regions like Karamoja where pastoralism is a dominant economic activity. Meanwhile, goats are reported to be kept by up to 39.2% of the households in the country. Karamoja still remained the region with the highest proportion (53.7%) of households keeping

goats. Generally, the highest proportion of cattle and goats still remain in the cattle corridor which covers parts of north eastern Uganda, central Uganda and the western parts of the country. The general trend of the proportions of both cattle and goat keeping households reveals that these animals are often kept together by the livestock keeping communities. These animals are majorly kept for social security, savings, milk, draught power, meat but sale for income has remained a limited function and animals are mostly sold to meet immediate cash needs (UBOS, 2009). Direct benefit from manure has also been demonstrated in some parts of the country such as Kabale where goat manure is used for vegetable production (Lund *et al.*, 2008).

Much as the numbers of the animals have increased significantly from the previous estimates (UBOS, 2007), the increases in livestock numbers have been surpassed by the human population. Major reasons for the increase in livestock numbers include increased interest in livestock keeping due to emerging markets in the region and return of relative peace and stability in most parts of the country. Although the challenge of increased animal productivity still lingers on, no significant changes in the productivity of the individual animals and their contribution to the livelihoods of the communities have been realised. There is therefore, an urgent need for interventions in production systems and genotype of the animals geared towards improving individual animal productivity.

2.3 Beef and goats meat production systems

2.3.1 Grazing based systems

Cattle and goats are traditionally reared under grazing systems using native pastures around the world. In Uganda, this accounts for more than 90% of the livestock production (Alan, 2002, UBOS, 2009). Ensiminger (2002) noted that pasture and range forages, along with other roughages, are the very foundation of successful beef cattle production. Adding that the principle function of beef cattle is to harvest vast acreages of forages, and with or without supplementation, convert these feeds into more nutritious and palatable products for human consumption. However, it is noted that substantial diversity exists among the major forage-producing areas in terms of plant species, annual precipitation, soil fertility, and other environmental factors. These factors either cumulatively or singly alter animal preferences for different browse species between the regions and seasons. The ultimate end is therefore, an

irregular performance of range animals (Drouillard and Kuhl, 1999; Ramirez-Orduna, *et al.*, 2008).

Preston and Leng (1987) argue that tropical forages are known to be lower in protein and soluble sugars but higher in cell wall contents. This significantly limits the performance of the indigenous animal breeds. Mpairwe et al. (2003) also projected that it would take 45 and 48 months for purely grazing Ankole x Friesian and pure Ankole bulls, respectively, to attain a target slaughter weight of 350 kg due to slow growth rates. In Tanzania, Msanga and Bee (2006) also found that Boran x Friesian bulls under extensive management could only attain 335 g/day average daily live weight gain. The fluctuations or low performance of animals could be attributed to fluctuations in herbage intake and dry matter digestibility (Miwa et al., 2007; Miller and Thompson, 2007). In addition to herbage quality fluctuations, animals raised under extensive management systems are also known to be vulnerable to ecto and endo parasites, which substantially reduce the productivity of these animals. Entrocasso (1986b) reported that gastrointestinal parasitism significantly reduced killingout percentage and associated carcass measurements of Friesian steers. Economic loses due to internal parasites have also been reported in grazing beef cattle (Maclean et al., 1992). Still notable is the high maintenance energy requirements for walking long distances during grazing that worsen the low productivity of grazing animals. Brosh et al. (2010) showed that grazing cows needed between 89 and 103 KJ/kgBW^{0.75}/day for walking and grazing compared to 42 to 47 KJ/kgBW^{0.75}/day required for standing. Meanwhile, Hata et al. (2005) also reported low fat deposition and energy content of body parts of grazing animals. This supports the argument that fat deposition is the least priority in the nutrient partitioning process of ruminants and only occurs when excess energy is available (Buttery et al., 2005).

Grazing systems in the rangelands are also significantly affected by high stocking rate which is a critical factor that influences the performance of animals. Traditional livestock keepers in Uganda are originally known to manage stocking rates by practising either nomadism or transhumance especially in non-settled systems. But the sedentary farmers are ever subjected to severe losses in livestock numbers during the dry season due to limited pastures and water. However, the increasing human population is arguably limiting the free movement of the non-settled livestock keepers as the rangelands have been encroached on for crop cultivation hence

hindering the flexibility of these systems. Various studies have reported the reduction in livestock productivity with increasing stocking rates (McCollum *et al.*, 1999; Owensby *et al.*, 2008; Derner *et al.*, 2008).

Therefore, so long as demand for livestock products continues to increase, sustainable and more efficient production systems will have to be adopted to mitigate the insufficiencies in supply of products of animal origin.

2.3.1.1 Performance of animals under grazing conditions

Nutrient supply to growing animals is a major challenge to efficient meat production especially in the tropics where feed quality and quantity fluctuate widely under grazing conditions. Generally, it is known that live weight gain of individual animals is dependent on the supply of amino acids and energy-yielding substrates delivered to the tissues. It is subsequently argued that, when adequate nutrients are supplied, growth of tissues continues until the genetic limit for protein synthesis of an individual animal is reached (Poppi and McLennan, 1995). Major factors that affect amino acid supply for tissue development are noted to include; protein content of the diet, its net transfer through the rumen and to the intestines as undegraded protein and microbial protein. In addition, the absorption of rumen undegradable protein (RUP) and microbial protein from the small intestine may also influence protein accretion in animal muscle tissue. Meanwhile, the deposition of protein into tissue is said to depend on the efficiency of use of the absorbed protein by the individual animal, which is in turn dependent on the availability of nonprotein energy-yielding substrates and limiting essential amino acids (Poppi and McLennan, 1995). It is therefore, the irregularity of the above mentioned factors in tropical pastures that translates into poor animal performance. Stobbs (1965) earlier stated that the level of intake and digestibility of tropical pastures determine animal performance. The authors further noted that, at early stages of maturity, the pastures are high in nutritive value but low in available dry matter. As they progress in maturity, fibre content of the pastures increases at the expense of minerals, amino acids and digestibility. Consequently, dry matter intake of animals is lowered. This results in subsequent limitation of growth performance of the animals. Therefore, supplementation would be a critical factor that aids efficient utilisation of pastures in the tropics.

2.3.2 Grazing with concentrate supplementation systems

Sole grazing in the tropics is associated with restricted nutrient intake by animals and hence the very poor meat production potential in these areas. It was observed much earlier in the review of Stonaker (1975) that weight changes of as low as 1 kg to as high as 264 kg per animal per year in cattle were notable in different tropical environments. Live weight changes of about 63 kg and 143 kg per animal per year have been reported by Mpairwe et al. (2003) and Msanga and Bee (2006) in Uganda and Tanzania, respectively. It is known that much as overall performances in livestock are affected by genotype, stage of development and other environmental factors such as feed quantity and quality are the most important factors limiting livestock productivity (Buttery et al., 2005). Energy and protein have been identified as the major nutrients limiting ruminant productivity (Church, 1971, Stonaker, 1975; Preston and Leng, 1987). In their study, McDonald et al. (2002) noted that steers weighing 300 kg and gaining 1 kg live weight per day would need 23 MJ of net energy for maintenance and 16 MJ of net energy for growth. The study indicates that the maintenance energy requirement accounted for 59% of total energy requirements. However, other factors such as insufficient fermentable nitrogen and sulphur, flow rate of digesta which is limited by high fibre content, imbalance in protein-energy ratio have also been cited (Preston and Leng, 1987; Ben Salem and Smith, 2008) as major limiting factors to efficient feed utilisation. Therefore, any supplementation strategy that not only increases nutrient supply to the animal but also improves dry matter intake and rumen function through enhanced microbial activity and passage rate of digesta can be considered beneficial to ruminant production. Stonaker (1975) noted that one of the earliest successes of supplemental feeding was the dramatic responses in reproductive performance achieved when cows in South African savannah were supplemented with bone meal as a phosphorous source.

Supplementation of grazing animals with molasses and maize grain as energy-rich feed stuffs for stall fed animals has shown tremendous improvement in animal performance in Uganda, although, energy-rich but protein deficient diets are known to produce poor performances and also depress pasture intake (Van Niekert, 1974). Supplementation targeting the most limiting nutrients, of which protein has been identified for animals relying on high fibre diets, is therefore beneficial (Smith *et al.*, 2005; Ben Salem and Smith, 2008). Many other studies have

demonstrated the importance of various protein sources as supplemental feeds for ruminant production in Uganda. These studies range from the use of legume tree leaves, urea and poultry litter (Kabi, 2003) and oilseed cakes (Okello *et al.*, 1994; Mpairwe *et al.*, 2003) for cattle and goat production. The studies have proved the invaluable potential of these feed resources for improved livestock production.

Further still, the significance of energy has also been established in studies involving molasses and cereal grains. Hu *et al.* (2007) and Salim *et al.* (2003) have generated reports that strengthen the evidence for continued use of these products for improved ruminant production. Reviews of Smith *et al.* (2005) and Ben Salem and Smith (2008) have revealed considerable amounts of information on the value of such products in many developing countries as source of feed for improved animal productivity. Therefore, for a more successful beef and goats' meat production regime in Uganda, supplementation with the locally generated agro-industrial by-products may hold the foundation for improved livestock productivity.

2.3.2.1 Effects of supplementation on performance of grazing animals

The limited quality of feed resources in the tropics was emphasised by Leng (1990) who observed that ruminant feeding in the tropics and subtropics considerably depended on lowquality materials (i.e. grazing pastures and crop residues). Despite the adaptation of most of indigenous animals to the nutrient stress, it can be argued that these adaptation mechanisms are only often sufficient to balance nutrient requirements for maintenance. This leads to the relatively poor productive and reproductive performance of the animals. Supplementation with protein and energy are therefore, common strategies often used in improving performance of ruminants depending on grazing pastures or crop residues. The supplementation strategies have ranged from aiming at improving intake of plant material with higher anti-nutritional factors (Dziba *et al.*, 2007) to the highly reported studies and reviews aimed at improving utilisation of fibrous feed materials (Leng, 1990; Poppi and McLennan, 1995; Klopfenstein, 1996; Caton and Dhuyvetter, 1997; Smith *et al.*, 2005).

However, one of the major setbacks of low-quality feed material to ruminants is the reduction in rate of passage, microbial growth rate and conversion efficiency of microbial nutrients (Klopfenstein, 1996). These factors have direct relationship with productive performance of

ruminants as they influence dry matter intake. Allen and Mertens (1988) stated that, fibre that is resistant to fermentation by rumen microbes represents a significant fraction of forage fibre and accumulates in the rumen relative to potentially fermentable fibre. This result's in limitation of dry matter intake due to rumen fill. Madsen *et al.* (1997) noted that physical regulation of feed intake resulting from rumen fill could be more pronounced in the tropics. Therefore, supplementation with feedstuffs rich in nitrogen and/or readily fermentable carbohydrates becomes necessary to improve the efficiency of feed utilisation through improving digestibility and degradation of fibre by rumen microbes (Khalili *et al.*, 1993; Tolera and Sundstøl, 2000). The improved feed digestibility and rumen fermentation characteristics results in increases in dry matter intake and subsequently availability of energy for tissue development in the animal and hence improvements in growth and meat yield. It is therefore justifiable to note that improvements in dry matter intake and rumen fermentation characteristics make supplementation of fibrous feed materials with concentrate a prerequisite for improved ruminant production.

2.3.3 Feedlot finishing of beef cattle and meat goats

Feedlot finishing is associated with lower requirements for land, improved overall production efficiency, reduced age of animals at slaughter and promotion of more efficient utilisation of feed resources (Cungen and Long worth, 1998). Bouwman *et al.* (2005) noted that traditional farming systems respond slowly to increasing demand for livestock products than modern technologies. They further argued that, there is a general gradual trend of livestock production towards intensification to meet the increasing demand for livestock products. Important to note in their argument is that, concentrates in form of grains and supplementation in form of fodder will substitute dependence on open rangelands for livestock feed resources. Ben Salem and Smith (2008), however, warned that such alternative feeding strategies that are more costly than the traditional practices are not often taken up by farmers.

Major successes in improvements in animal performance at the feedlot are associated with increased nutrient supply and the remarkably reduced maintenance energy requirements as a result of reduced activity, especially walking. Osuji (1974) showed that grazing sheep spent 30% more energy than their housed counter parts. Caton and Dhuyvetter (1997) also reported that energy spent by muscle on chewing, ruminating and locomotion accounted for 23% of energy

requirements of extensively grazing animals. Therefore, at the feedlot, such amounts of energy are saved by the animals and can be partitioned towards tissue development. However, the benefits of intensive management at the feedlot vary with various factors such as age of the animals, body size, duration at the feedlot and ultimately the quality of feeds.

Earlier feedlot placement is said to accelerate finishing and produce young, higher marbled beef, but with lower carcass weights. Feeding bulls in an early-weaned system is also reported to be a viable management option. Meanwhile, it is noted that as feedlot entry age increases in bulls, intramuscular fat deposition is increasingly impeded, and the possibility for over-weight carcasses increases (Schoonmaker *et al.*, 2002). In a related study on the Zavot cattle in Turkey, Aksoy *et al.* (2006) found that slaughter characteristics are lower for young cattle and that the correlation between body weight, body measurements, slaughter characteristics and carcass measurements are high.

Body size as an individual trait is also said to be very important since it is related to potential growth at every stage of the development process (Webster, 1986). In addition, body size is reported to affect the whole production system, due to its influence on aspects such as the food conversion efficiency, the time taken to meet a specific market finishing degree, or the final quality of the obtained product (Romera *et al.*, 1998). Therefore, appropriate animals and management factors influence success in a feedlot.

2.4 Genotype differences in performance

Early maturing and large framed animals are known to grow faster than late maturing and small framed animals (Webster, 1986). In beef production, there is evidence of differences in efficiency between breeds (Wright *et al.*, 1994) and between animals of the same breed but differing in body size (Ferrer *et al.*, 1995). However, Katongole (2003) observed no difference in DM intake and feed conversion ratio between the indigenous cattle and Ankole x Friesian bulls in Uganda. However, various studies have shown performance differences between tropical breeds of cattle and breeds of temperate origin (Gregory *et al.*, 1995). Boran cattle are reportedly the most productive beef breeds in the tropical regions (Creek, 1972; Rege, 1998).

Fitzhugh (1978) concluded that important genotype x environment interactions could affect production efficiency as a consequence of differences in energy requirements and output. Theoretical studies (Illius and Gordon, 1987) indicated that body size could affect an animal's ability to harvest herbage in conditions of low pasture availability, with larger animals being at a disadvantage in such situations. This, therefore, implies that local small framed genotypes would have an advantage over the large framed exotic breeds of temperate origin in the tropics.

According to Osoro *et al.* (1999), live weight change is significantly affected by the interaction between various treatments and different breeds of sheep over grazing season. Further adding that, there is significant genotype x environment interaction affecting diet selection and animal performance. Osoro *et al.*, (1999) further demonstrated the lesser ability of large genotypes to exploit conditions of low herbage height as a consequence of their grazing behaviour and their higher absolute nutrient requirements. Cameron *et al.* (2001) also found that feed intake, efficiency of feed conversion and slaughter characteristics were greater in Boer crosses with Spanish and Angora goats than the pure Spanish.

These results indicate the significant effect of varying genotypes on overall performance of animals. The available literature is, therefore, interpreted to mean that optimal feedlot productivity is dependent on different genotypes of animals and their relative adaptability to the environment.

2.5 Blood metabolite profiles of ruminants

Metabolic profiles are becoming important in obtaining information on the nutrition and health status of ruminants (Ndlovu, 2009). Agenas *et al.* (2006) noted that concentrations of nutritionally-related blood metabolites could be more useful indicators of short-term nutritional changes. Grünwaldt *et al.*, (2005) also noted that breed, seasonal and physiological state differences in some blood metabolites could be attributed to; chemical composition of feed ingested, environmental temperature, nutrient content of forage, animal age and cattle foraging experience. The author further states that, glucose levels of 15% of the beef cattle in the rangelands of Argentina were below the reference range of greater than 2.5 mmol/L and that blood urea levels were within the optimum range less than 3.6 mmol/L. Sugimoto *et al.* (2003) also reported that supplementation of Wagyu steers with soybean meal and corn gluten meal

during the grazing period significantly increased the blood urea nitrogen (BUN). Meanwhile, according to studies by Boonprong *et al.* (2007), blood plasma urea, glucose and NEFA varied between breeds and sexes of Thai indigenous cattle and Simmental x Brahman crosses grazing tropical pastures. Therefore understanding the blood metabolite profile of the indigenous cattle and goat breeds and their crossbreds under different feeding system would add to the information needed to establish the appropriate feeding systems for optimum production levels.

2.6 Rumen environment

Short chain volatile fatty acids are known to serve as the major source of energy for ruminant animals. However, various factors are known to affect the concentration of these acids. Factors such as supplementary feeding with high energy and protein diets, feeding frequency, fasting; quality of pastures, environmental temperature, animal handling and transportation; are known to significantly affect the volatile fatty acid composition in the rumen (Knox and Ward, 1961; Galyean *et al.*, 1981; Sunagawa *et al.*, 1997; Sugimoto *et al.*, 2003; Dalton *et al.*, 2008; Owens *et al.*, 2008;). Increased propionate proportion in the rumen and reduced acetate:propionate ratio is associated with increased growth rate (Shaw *et al.*, 1960) as propionate is said to be directly taken almost entirely by liver and used for synthesis of glucose (Forbs, 2007).

Rumen pH and ammonia-nitrogen are also known to be key factors affecting the efficiency of feed utilisation by ruminants. Moderate reductions in rumen pH to about 6.0 are said to reduce fibre digestion in the rumen with no effects on microbial population while further decreases below 5.5 reportedly reduce growth, microbial population and may ultimately inhibit fibre digestion in rumen (Hoover, 1998). However, it is known that concentrate diets can be used to manipulate rumen pH; high levels of concentrates containing soluble sugars in the diets of ruminants depress pH (Shriver *et al.*, 1986). Therefore, recommended requirements of rumen ammonia for optimal microbial growth are between 5mg/100ml (NRC, 1984) and 10g/dL (Leng, 1990). Nutritional management practices that optimise the rumen environment are therefore paramount in improving the productivity of ruminants.

3.0 Effects of feeding system on performance of Ankole cattle and its Boran and Friesian crossbreds

3.1. Introduction

More than 95% of meat in Uganda is produced by pastoral communities under subsistence farming in settled or non-settled production systems in the rangelands (Mpairwe, 1999). Much as the communities have lived with these systems for long and the animals have valuable traits for meat production, the systems have low productivity due to very low levels of input use and poor management practices. Ever increasing human population also continues to constrain and suffocate extensive system which has for so long dominated livestock industry. Moreover, extreme seasonality of herbage quantity and quality, ecto- and endo-parasites, endemic diseases, and heat stress from high temperatures further aggravate the poor productivity of the systems. Mpairwe et al. (2003) found that Ankole cattle on grazing gained only 194 g/day compared to 350 g/day of grazing animals supplemented with high energy and protein diets. The study demonstrated the inherent potential the local animals have under improved management. However, extreme values attached to numbers of live animals for social security and prestige instead of individual animal productivity among the cattle keeping communities constitutes further limitation to productivity improvement through intensive management. This coupled with the remoteness of markets to the cattle keeping areas overshadow the meat production potential of the animals.

The existing systems of production have to supply the much needed but never sufficient livestock products with meat being one of the most critical. However, large amounts of agroindustrial by-products which hold a huge potential as fibre, protein and energy sources for beef production under intensive or semi-intensive management systems are generated in various parts of the country. Maize which is a staple food in Uganda is grown in all the cropping systems of the country (UBOS, 2007) hence producing great amounts of stover at harvest and considerable amounts of maize bran at milling. The maize stover which can constitute up to 40 % biomass yield of maize crop (Tolera *et al.*, 1999) is mainly being used as source of fuel, mulch and also often burnt in the gardens (Mpairwe, 1998) due to its bulkiness. Although invariably high in fibre and low in digestibility and nitrogen, crop residues like maize stover have contributed significantly to development of improved livestock production in various parts of the world (Preston *et al.*, 1967; Creek, 1972; Preston and Leng, 1987; Sindhu *et al.*, 2002; Baset *et al.*, 2003). Furthermore, molasses produced in a proportion of about 300 g/kg of sugar (MFED, 2006), is also being generated in considerably large amounts from three major sugar industries in Uganda. It is therefore, worth noting that a greater potential exists in alternative feed resources in Uganda that can be effectively used to improve the current low productivity of the meat animals in Uganda.

Arguably, recent investigations have reported a higher natural potential in tropical cattle breeds for a good number of productive traits than has often been believed (Köhler-Rollefson, 1997, 2001, cited by Ndumu *et al.*, 2008). The Ankole cattle which constitute about 30% (UBOS, 2009) of the indigenous cattle population in Uganda have since time immemorial contributed to the livelihood of a good proportion of the livestock keepers in Uganda. However, growing interest in semi-intensive and intensive beef and milk production has led to gradual increase in the numbers of the improved Boran and Holstein Friesian breeds in the country. This, however, carries a negative impact on the local animal genotypes since the local animals are often easily neglected in preference for the new genotypes which are promoted for being high yielding in terms of milk and meat. Rege (1999) reported that the Ankole cattle (Bahima) were vulnerable to extinction due to crossbreeding and interbreeding. Therefore, the aim of this study was to evaluate the potential of Ankole cattle as compared to its Boran and Friesian crossbreds for improved beef production under different feeding systems.

3.2. Materials and methods

3.2.1. Description of the study location

This study was conducted between July and December, 2007 in a ranch operation located in Nakaseke district which is found in central Uganda about 120 km north of the capital Kampala. Nakaseke district lies within the cattle corridor of Uganda at an altitude of 1080 m at 1 ° 0" 0' North and 32⁰ 19" 60' East. Much as the area receives a total mean annual rainfall ranging from 800 - 1233 mm, the total rainfall for 2007 was 1263 mm and rainfall between July and December was 639 mm. Annual mean temperatures are about 28°C maximum and 16°C minimum. Major pasture species in the area include *Brachiaria spp, Cymbopogon spp, Themeda spp, Panicum spp, Chloris spp* and *Laudetia spp*, while *Acacia* though sparsely distributed, is the most

common leguminous shrub species. *Sporobolus* which is a less palatable grass species occupied a large part of the grazing area.

3.2.2. Animals and treatment

A 3 X 3 factorial treatment structure was used to randomly allocate 144 young bulls; 48 pure Ankole (ANK), 48 Ankole-Boran (AXB) and 48 Ankole-Friesian crossbreds aged between 12 and 24 months, to three feeding systems. The initial weights of the bulls were $182.3 \pm 27, 205.9$ \pm 26 and 188 \pm 22 kg for ANK, AXB and AXF, respectively. The ANK and AXB bulls were selected from the ranch while the AXF were bought from the local livestock markets. Bulls were stratified in to two weight groups. Animals in each weight group within genotypes were randomly allocated to the different feeding systems. The feeding systems included solely grazing (control, T1), grazing with concentrate supplementation overnight (T2) and fully confined feedlot finishing (T3) with bulls fed ad libitum on maize stover and concentrate which accounted for 60% of estimated daily feed intake. The concentrate comprised 70 % maize bran, 20 % cotton seedcake and 10 % molasses, formulated targeting 800g average daily live weight gain (NRC, 1984). For intake studies, four bulls in each genotype and feeding system were fed in a pen which formed the experimental unit in T2 and T3, although intake of pasture was not estimated due to the non-uniform nature of the rangeland pastures and the associated complexities. However, 16 bulls per genotype were allotted for the grazing system of feeding. Individual animals formed the experimental units for data collection on blood metabolites, rumen fermentation characteristics, growth and slaughter characteristics.

3.2.3. Feeding and management

Bulls were given a 28-day adaptation period within which they were treated for internal parasites while external parasites were controlled through weekly dipping in the course of the trial period. During the experimental period, grazing bulls were released by 08:30 hours and returned by 17:30 hours. At this time, the grazing and concentrate supplemented (T2) bulls were returned to their pens for concentrate. In T3, concentrate was offered targeting 60% of the daily dry matter intake per pen. Total feed offer per day included an additional 10% of previous day's intake in order to achieve *ad libitum* voluntary intake. Estimated proportion of concentrate was offered target at 16:00 hours.

while maize stover was offered *ad libitum*. Free access to water and rock salt was provided to all penned animals. Plate 3.1 shows feedlot animals in the experimental pens while Plate 3.2 shows grazing animals.



Plate 3.1: Feeding bulls at the feedlot



Plate 3.2: Grazing animals at the time of study

3.2.4. Feed intake measurements

Daily feed offer and refusal weights were taken and recorded for each pen to determine DM intake in T2 and T3. Representative concentrate, maize stover and refusal samples were taken weekly and each pooled to make monthly samples for chemical analysis. Pasture DM intake was not determined nevertheless; monthly pasture samples were taken and pooled for chemical analysis.

Feed efficiency (FE) in the feedlot was computed as a proportion of the daily DM intake to the daily live body weight gain. However, the following formula was used to determine the efficiency of concentrate utilization in the grazing and concentrate supplemented bulls. This was based on the assumption that the additional daily live weight gains of bulls in T2 over T1 resulted from concentrate intake only, a simulation from Moore *et al.* (1999).

$$FE = \frac{Daily \ concentrate \ DM \ int \ ake \ in \ T2 \ (kg)}{ADG_{T2} \ (kg) - \ ADG_{T1} \ (kg)}$$

Where: ADG_{T1} = Average daily live body weight gain of bulls in T1

 ADG_{T2} = Average daily live body weight gain of bulls in T2.

3.2.5. Body weight measurements

Initial body weights of bulls were determined by two consecutive days of weighing and subsequent weights were taken every 14 days. All weights were taken before feeding. Average daily body weight gain was determined as a proportion of total weight change to the feeding period of 120 days.

3.2.6. Blood sampling and analysis

Blood samples were taken between 08hrs and 09hrs at slaughter. About 3ml samples were transferred into heparinised vacutainers containing ethylenediaminetetraacetic acid (EDTA) as anticoagulant and another 3ml transferred into non-heparinised vacutainers. Samples in the heparinised vacutainers were temporarily stored in an ice-box packed with dry ice and transferred within one hour to a commercial laboratory. These samples were centrifuged (15 min

at 1600 x g, 4 °C) and stored at -40 °C for later analysis. Plasma samples were then analysed for plasma glucose (Nerono diagnostic reagents, Nicosia, Cyprus) and lactate (DiaSys diagnostic systems GmbH, Holzheim, German, for lactate) using a Cobas Integra 400/700/800 analyzer (Roche diagnostics GmbH, D-68298 Mannheim, USA). Samples stored in the non-heparinised vacutainers were allowed to clot and serum was extracted and stored at a temperature of below negative 18 °C until analysis for blood urea nitrogen (BUN), total protein (TP), albumin and globulin using the same analyser as in glucose and lactate.

3.2.7. Rumen fluid sampling and analysis

Immediately after slaughter, the stomach was sectioned and the rumen contents were sampled from each animal while there was still visible rumen motility. The contents were strained through three layers of cheese cloth to obtain about 200 ml of rumen fluid in plastic bottles. Rumen fluid pH was taken immediately using a glass rod probe digital pH meter (Knick, Portamess[®] 922) and recorded. Three drops of concentrated hydrochloric acid were added to each sample after pH reading to terminate further microbial activity. Samples were packed in an ice-box filled with dry ice before taken for storage at -18 ^oC within two hours until further analysis. A simulation from the methods of Cottyn and Boueque (1968) and Erwin *et al.* (1961) were used for the analysis of volatile fatty acids as summarized below.

Following thawing at room temperature, 1ml sub-samples were taken and 30µl of 34 % orthophosphoric acid was added and left to stand for 30 minutes. Samples were centrifuged using a Biofuge centrifuge (pico-Heraeus, Kendro) at 12,000 rpm for 10 minutes. Supernatants were extracted and transferred to GC-vials and immediately stored at -20 °C before analysis. After thawing of supernatant at room temperature, 1µl was analysed on Perkin Elmer Model 8500 gas chromatograph (GC) equipped with flame-ionisation detector (FID) using TR-FFAP column - 30m x 0.25mm (internal diameter) and a stationary phase of 0.25 µm thickness (Teknokroma). Hydrogen gas was used as a mobile phase at 12 kPa column head pressure. The injector temperature was set at 260°C and detector at 330°C. The oven was programmed at 110 °C, 8 °C/min to 190 °C, then 20 °C/min to 230 °C where it was left Isothermal for 1 minute before cooling for the next run. The components eluting from the column were detected by flame-ionisation detector (FID). The detector output signal was captured and recorded using Perkin Elmer interface 9000 linked to computer with Turbochrome 4 software data system for

processing and storage of chromatographic data. The peaks were identified by comparison with standard chromatogram of standard mixture of seven VFAs (Volatile Acid Standard Mix from SUPELCO, Bellefonte, PA, USA) analysed using the same procedure.

3.2.8. Measurements at slaughter

At the end of the feeding period, eight bulls with the highest live weights per treatment were selected and slaughtered. Bulls were transported for eight hours to a commercial abattoir located about 120 km from the ranch and were slaughtered after an overnight fasting. Each bull was weighed before slaughter to determine the slaughter weights. Hot carcass weights were taken immediately after removal of non-carcass components. Dressing percentage was computed as a proportion of the hot carcass weight to the slaughter weight. Weights of head, skin with tail, feet, heart, lungs with trachea and oesophagus, kidney without fat, liver, empty stomach (rumen, reticulum, omasum and abomasum) and empty intestines with caecum were taken and recorded as non-carcass components. Omental fat, mesenteric fat, kidney fat, pericardial fat and scrotal fat were also weighed and recorded. Omental and mesenteric fat were summed as digestive tract fat. Total internal fat was computed as the sum of the digestive tract fat, kidney fat and pericardial fat.

3.2.9. Gross margin analysis

Costs that varied in the course of the trial and the value of both the carcass and non-carcass components at market price were used to carry out a gross margin analysis. Variable costs recorded included cost of purchasing bulls, management costs, costs of veterinary services, feed costs and marketing costs. Total revenue was computed as value of each animal after dressing.

3.2.9.1. Purchasing cost of bulls

Before start of experiment, each bull was valued at Ush. 1,000 per kilogram live body weight following current prices at local auction markets.

3.2.9.2. Cost of management

Management cost was estimated according to the number of personnel employed per feeding system and their respective wages for the four months of the trial (Table 3.1).

Feeding system	Number of personnel	Wage (Ush/person/month)	Total wage (Ush/month/)	Total wage (Ush/4 months)	Cost/animal (Ush)
Sole grazing	1	30,000	30,000	120,000	2,500
Grazing plus concentrate supplementation	2	45,000	90,000	360,000	7,500
Feedlot finishing	3	45,000	135,000	540,000	11,250

Table 3.1 Cost of management

3.2.9.3. Veterinary costs

Cost of veterinary services was computed as the sum of dipping cost and cost of deworming per animal. Dipping cost was estimated according to current price of acaricide (Tsetse tick® - deltamethrin compound (Ush. 75,000)), rate of dipping per feeding system and the amount of acaricide and water mixture an animal removes during dipping. Water removed during dipping was estimated to be 2.5 litres/animal/dipping based on changes in volume of the dip tank. Solely grazed animals as well as those on grazing and supplementation were dipped once a week while feedlot finished animals were dipped once a fortnight. Deworming cost estimated according to current price of dewormer (Lefavas (Ush. 30,000/litre)) and rate of dosage per animal (2.5ml/kg live body weight).

3.2.9.4. Cost of feeding

Feed costs included, estimated cost of grazing pastures for the four months of the trial and the cost of concentrate. The cost of grazing pastures was estimated based on current rates of renting grazing land per animal per year (Ush. 40,000). Concentrate cost was computed through least cost formulation using solver in Microsoft excel (Appendix 1). Unit costs of feedstuffs included purchasing price of feed and transportation costs.
3.2.9.5 Marketing costs

Marketing costs included movement permit (Ush. 3,000/animal) and slaughter charges at the abattoir (Ush. 12,000/animal). Transport cost was not considered as part of marketing cost as it was dependent on distance and was constant per truck regardless of number of animals transported.

3.2.9.6 Total revenue and gross margin

Carcass and non-carcass components were valued according to the prevailing abattoir price (Appendix 1). Gross margin was computed as the difference between the total variable cost and total revenue.

3.2.10. Chemical analysis of feeds

Concentrate and pasture samples were analysed for dry matter (DM), crude protein (CP), ether extracts (EE), calcium (Ca), phosphorous (P) and total ash according to the procedures of AOAC (1990). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analysed using the procedures of Van Soest *et al.* (1991). Gross energy (GE) was analysed using the bomb calorimeter (GALLENKAMP Autobomb, UK). Details of chemical composition of feeds are presented in Table 3.2.

3.2.11. Statistical analysis

Data was analysed using the general linear model (GLM) procedures of Statistical Analysis Systems (SAS, 2003). Data on feed intake was analysed using genotype as a single factor adjusted for initial weight as covariate. A 3 x 3 factorial structure was used for the analysis of data on growth, slaughter characteristics, blood metabolites and rumen environment with genotype and feeding system as the factors each at three levels. Genotype and feeding system interactions were included in the model. Slaughter weight, carcass weight and hot carcass dressing percentage were also corrected for initial weight as covariate.

	Concentrate	Maize stover	Pasture
Dry Matter (g/kg)	877	655	420
Gross Energy (MJ/kg DM)	17.4	15.2	15.3
Crude Protein (g/kg DM)	150.8	53	90
Neutral Detergent Fibre (g/kg DM)	285.5	692.6	558.1
Acid Detergent Fibre (g/kg DM)	76	405.6	346.6
Acid Detergent Lignin (g/kg DM)	26.4	63.2	59.2
Ether Extract (g/kg DM)	94.2	4.2	9.8
Ash (g/kg DM)	52.2	103.5	80.2
Calcium (g/kg DM)	1.5	7.8	8.2
Phosphorous (g/kg DM)	4.2	0.3	4.5

 Table 3.2 Chemical composition of feeds

3.3. Results

3.3.1. Genotype effects on feed utilization

Characteristics of feed utilisation in the different feeding systems are summarised in Figures 3.1 and 3.2. There was significant (P < 0.01) genotype effect on concentrate dry matter (DM) intake and feed conversion ratio of bulls in the grazing and concentrate supplemented feeding system (T2). The crossbreds had higher dry matter intake than the pure Ankole bulls (Figure 3.1A and 3.1B). The pure Ankole bulls and the crossbreds with Boran had a lower dry matter intake per live weight gain than the Friesian crossbreds (Figure 3.1C).

Daily DM intake in the feedlot (T3) also significantly (P < 0.01) varied between genotypes (Figure 3.2). Pure Ankole bulls and the crossbreds with Friesian had higher (P < 0.05) DM intake compared to the crossbreds with Boran (Figure 3.2A). Total DM intake subsequently varied in a similar manner (Figure 3.2B). The crossbreds with Friesian were the most efficient (P < 0.001) in feed utilisation compared to the pure Ankole which were also more efficient (P < 0.05) than the crossbreds with Boran (Figure 3.2C).



Figure 3.1A: Least squares means showing effects of genotype on concentrate dry matter intake in grazing bulls supplemented with concentrate (T2)



Figure 3.1B: Least squares means showing effects of genotype on total concentrate dry matter intake in grazing bulls supplemented with concentrate (T2).



Figure 3.1C: Least squares means showing genotype differences in efficiency of concentrate utilisation of grazing bulls supplemented with concentrate (T2)



Figure 3.2A: Least squares means showing effects of genotype on dry matter intake at the feedlot (T3)



Figure 3.2B: Least squares means showing effects of genotype on total dry matter intake at the feedlot (T3)



Figure 3.2C: Least squares means showing genotype differences in efficiency of feed utilization at the feedlot (T3)

3.3.2. Blood metabolites and rumen fermentation characteristics

Feeding system and genotype effects on blood metabolites and rumen fermentation characteristics are presented in Table 3.3. Genotype and feeding system effects were significant (P < 0.01) on plasma glucose and lactate. Total protein, albumen, globulin and blood urea nitrogen (BUN) were not affected by genotype. Higher glucose levels occurred in the purely grazing bulls except in the AXF. Glucose levels generally ranged between 5.1 mmol/L to 7.5 mmol/L. Lowest glucose levels were observed in the feedlot (T3). Blood lactate levels ranged between 8.2 and 16.9 mmol/L with higher levels occurring in the pure grazing bulls in all genotypes. Unlike in the pure Ankole bulls where lowest lactate levels occurred at the feedlot, lowest lactate levels of the crossbreds occurred in grazing bulls supplemented with concentrate. Blood urea nitrogen was generally higher in T3 than in T2 and T1 for all genotypes although, significant difference (P < 0.01) was only observed within pure Ankole and the AXF crossbreds. Purely grazed bulls had the lowest values of BUN in ANK and AXB while lowest BUN level in AXF occurred in T2.

Variation of the rumen fermentation characteristics with genotype and feeding system is presented in Table 3.3. Apart from acetate, butyrate and acetate:propionate ratio; genotype effects were significant on all other rumen fermentation parameters measured. Rumen pH (P < 0.05), propionate (P < 0.001), isobutyrate (P < 0.01), isovalerate (P < 0.01) and valerate (P < 0.01) were among those affected. Rumen pH ranged from 6.6 in AXF (T3) to 7.4 in ANK (T2). There were also significant (P < 0.05) genotype and feeding system interaction on rumen pH. In T3, AXF had the lowest pH, yet in T2, lowest pH was obtained in AXB. Acetate:propionate ratio was significantly (P < 0.01) lower in AXF (T3) but not different from AXF (T2). Highest ratio was obtained in AXF (T1) which however, was not different from ANK (T1 and T2) and AXB (T2). It could be seen that acetate:propionate ratio was lowest in AXF among genotypes and T3 among feeding systems.

Parameter		ANK			AXB		A	XF			Significance			
	T1	T2	T3	T1	T2	T3	T1	T2	T3	SEM	Gen	FS	Gen*FS	
Blood metabolites														
Glucose (mmol/L)	5.8 ^b	5.2 ^b	5.2 ^b	7.5 ^a	5.9 ^b	5.3 ^b	5.2 ^b	5.2 ^b	5.1 ^b	0.5	**	*	ns	
Lactate (mmol/L)	13.8 ^{ab}	11.9 ^b	11.2^{bc}	16.9 ^a	11.5 ^{bc}	12.2 ^b	10.2^{bc}	8.2 ^c	9.6 ^{bc}	1.8	**	*	ns	
Total protein (g/L)	74.1	75.2	78.7	74.5	77.3	76.8	73.3	71.5	76.1	3.2	ns	ns	ns	
Albumin (g/L)	25.1 ^c	29.0^{bc}	34.8 ^{ab}	29.6 ^b	32.4 ^{ab}	35.2 ^a	29.8 ^b	31.2 ^b	33.0 ^{ab}	2.0	ns	**	ns	
Globulin (g/L)	49.0 ^a	46.1	44.0	45.0	44.9	41.6	43.4	40.5	43.1	3.0	ns	ns	ns	
BUN ¹ (mmol/L)	4.9 ^b	5.7 ^b	6.7 ^{ab}	5.0 ^b	6.7 ^{ab}	7.1 ^{ab}	5.5 ^b	4.9 ^b	8.1 ^a	0.9	ns	**	ns	
Rumen environment ¹														
Rumen pH	7.2 ^{ab}	7.4 ^a	7.2 ^{ab}	7.0 ^b	7.3 ^a	7.2 ^{ab}	7.2 ^{ab}	7.2 ^{ab}	6.6 ^c	0.1	*	*	*	
Acetate (%)	46.2 ^{ab}	47.9 ^a	40.6 ^b	42.0 ^b	48.5 ^a	43.9 ^a	50.7 ^a	44.8 ^{ab}	44.2 ^{ab}	2.2	ns	**	**	
Propionate (%)	17.9 ^c	17.1 ^c	22.5 ^{bc}	20.4^{bc}	19.6 ^c	22.0 ^{bc}	17.0 ^c	26.2 ^b	33.1 ^a	2.0	***	***	**	
Isobutyrate (%)	6.2 ^{ab}	7.1 ^a	7.1 ^a	4.7 ^{ab}	6.1 ^{ab}	7.7 ^a	5.8 ^{ab}	4.2 ^{ab}	3.4 ^b	1.3	*	ns	ns	
butyrate (%)	14.0	13.2	11.9	18.6	12.4	14.9	12.8	13.0	13.4	2.0	ns	ns	ns	
Isovalerate (%)	12.2 ^a	11.3 ^a	12.8 ^a	9.9 ^a	10.7 ^a	13.6 ^a	10.6 ^a	8.5 ^{ab}	4.1 ^b	1.9	**	ns	**	
valerate (%)	3.5 ^{bc}	3.9 ^b	5.0 ^a	5.1 ^a	3.3 ^{bc}	3.8 ^b	3.0 ^{bc}	3.3 ^{bc}	2.6 ^c	0.4	**	ns	**	
Acetate:Propionate	2.6^{ab}	2.8 ^a	1.8 ^{cd}	2.1 ^{bc}	2.6^{ab}	2.2 ^{bc}	3.0 ^a	1.8 ^{cd}	1.3 ^d	0.2	ns	***	***	

Table 3.3: Least squares means showing effects of genotype and feeding system on blood metabolites and rumen fermentation parameters

ANK-Pure Ankole, AXB-Ankole-Boran crossbred, AXF-Ankole-Friesian crossbreds, T1-Sole grazing, T2-Grazing plus concentrate supplement, T3-Feedlot finishing, Gen-Genotype, FS-Feeding system, ¹BUN – Blood urea nitrogen; ^{abcd} means within rows with similar superscripts are not different (P>0.05); *-P<0.05; **P<0.01; **P<0.001; ns-not significant (P>0.05).

¹ Rumen fluid samples were taken after about twenty hours of fasting as described in the methodology, the aim was to evaluate fermentation characteristics even after the duration of fasting stated

3.3.3. Growth performance

Growth performance characteristics as affected by genotype and feeding system are presented in Table 3.4. There were significant genotype and feeding system effects on weight changes but no interaction effects between them. Friesian crossbreds had significantly (P < 0.05) higher live body weight change compared to ANK and AXB which had the lowest change in live body weight. Final live weight in T3 was significantly (P < 0.001) higher compared to T2 and T1 in all genotypes. This was translated into higher (P < 0.001) live body weight changes of bulls in T3. The total live body weight change of bulls in T3 was higher by at least 29 kg and 69 kg as compared to T2 and T1, respectively, in all genotypes. Least square means of body weight change in T2 were also higher by at least 25 kg than that of T1 in all genotypes. Plate 3.3 shows one of the best performing bulls in the study.

Growth rate of bulls in the course of the trial are further illustrated in Figure 3. Rate of growth generally increased with time although the increases were more clearly seen in T1. Maximum growth rate in T1 (Figure 3.3A) and T2 (Figure 3.3B) occurred in the third month for all genotypes while maximum growth rate in T3 (Figure 3.3C) occurred in the fourth month of the study in all genotypes. Reduction in growth rates were observed in the last month of the trial in T1 and T2. Plate 3.4 shows carcasses after dressing at the abattoir.



Plate 3.3: Experimental bulls at the weighing crash

Parameter		ANK		AXB			AXF				Significance [#]	
	T1	T2	T3	T1	T2	Т3	T1	T2	T3 S	SEM	Gen	FS
Body live weigh	nt changes (kg											
Initial weight	196.1 ^a	192.3 ^b	168.4 ^c	213.8 ^a	206.1 ^a	186.0 ^b	185.3 ^{bc}	193.8 ^{ab}	174.1 ^{bc}	8.2	**	***
Final weight	226.6 ^d	258.4 ^c	288.0 ^b	220.1 ^d	257.5 ^c	287.1 ^b	233.9 ^d	260.3 ^c	304.0 ^a	4.8	**	***
Weight change	34.7 ^d	65.7 ^c	96.4 ^b	32.8 ^e	65.3 ^c	90.2 ^b	44.8 ^d	67.7 ^c	111.0 ^a	3.7	**	***
ADG	0.27 ^d	0.55 ^c	0.80 ^b	0.27 ^d	0.54 ^c	0.75 ^b	0.37 ^d	0.57 ^c	0.93 ^a	0.04	**	***

Table 3.4: Least square means showing effects of genotype (Gen) and feeding system (FS) on growth characteristics

^{abc}Means with different superscripts within a row are different at P < 0.05; **P < 0.01; ***P < 0.001; ANK-Pure Ankole, AXB-Ankole-Boran crossbred, AXF-Ankole-Friesian crossbreds, T1-Sole grazing, T2-Grazing plus concentrate supplement, T3-Feedlot finishing, Gen-Genotype, FS-Feeding system, ADG – average daily gain. [#]Interaction effects were not significant on all parameters and are not presented in the table.



Figure 3.3A: Variation of average daily gain of grazing (T1) animals with time



Figure 3.3B: Variation of average daily gain of grazing and supplemented (T2) animals with time



Figure 3.3C: Variation of average daily live weight gain of feedlot finished (T3) animals with time

3.3.4. Slaughter characteristics

Effects of genotype and feeding system on slaughter characteristics are presented in Table 3.5 while selected carcasses are presented in Plate 3.4. Genotype effects were not significant on both carcass and non-carcass components except for the head, skin and tail, feet, and scrotal fat. The pure Ankole had the heaviest heads compared to AXB and AXF in all feeding systems (Table 3.5). Although AXF had the lightest skin and tail weights in all feeding systems, their feet were the heaviest compared to ANK and AXB. Scrotal fat was more deposited in ANK and AXB than in AXF.

Feeding system, significantly affected all slaughter parameters measured (Table 3.5). Among the carcass components, slaughter and hot carcass weights were affected (P < 0.001) while hot carcass dressing percentage did not vary with feeding system. Slaughter weights were consistently higher in T3 for all genotypes. Hot carcass weights of T3 were heavier than T2 by 13kg, 6.6kg and 20.6kg in the ANK, AXB and AXF genotypes, respectively. Differences in hot carcass weight between T3 and T1 were 37.7 kg, 31.7 kg and 35.5 kg for ANK, AXB and AXF genotypes, respectively. Hot carcass dressing percentage ranged from 49 % in T1 to 53 % in T3 in all genotypes. Meanwhile, non-carcass components most significantly (P < 0.001) affected by feeding system were ; skin and tail, feet, liver, kidney, spleen, empty intestines, digestive tract fat, total internal fat and scrotal fat. Head, heart, lungs and empty stomach were also affected (P < 0.01) by feeding system. The values were such that, T3 and T2 consistently had heavier weights of non-carcass components than in T1.



Plate 3.4: Carcasses at the abattoir

Parameter		ANK			AXB		A	XF		<u>Significance</u> ¥		
	T1	T2	T3	T1	T2	T3	T1	T2	Т3	SEM	Gen	FS
Carcass compone	nts (kg)											
Slaughter wt	218.5 ^c	252.7 ^b	262.4 ^{ab}	234.5 ^c	249.5 ^b	260.4 ^{ab}	221.7 ^c	256.8 ^b	275.1 ^a	5.6	ns	***
Hot carcass wt	107.5 ^c	125.9 ^{ab}	134.4 ^a	115.9 ^{bc}	135.2 ^a	134.7 ^{ab}	112.7 ^c	129.5 ^a	138.1 ^a	4.1	ns	***
HCD ^{\$} (%)	49.3	50.0	52.3	49.0	53.1	51.8	51.1	50.4	51.8	1.3	ns	ns
Non-carcass comp	ponents (l	kg)										
Head	17.0 ^b	19.4 ^a	20.3 ^a	14.3 ^c	15.8 ^{bc}	16.2 ^b	14.5 ^c	15.2 ^c	17.0 ^b	0.69	***	**
Hide and tail	20.1 ^{cd}	22.3 ^{bc}	26.0 ^a	22.3 ^{bc}	25.3 ^{ab}	27.2 ^a	18.2 ^d	18.3 ^d	23.5 ^b	1.06	***	***
Feet	6.0 ^c	6.9 ^{ab}	6.9 ^{ab}	6.2 ^{bc}	6.5 ^{bc}	7.0 ^a	6.6 ^b	6.9 ^a	7.3 ^a	0.19	**	***
Heart	1.0 ^c	1.1 ^{bc}	1.2 ^{ab}	1.1 ^{bc}	1.1 ^{bc}	1.1 ^{bc}	1.1 ^{bc}	1.1 ^{bc}	1.3 ^a	0.05	ns	**
Liver	3.5 ^c	4.1 ^{bc}	4.5 ^{ab}	3.7 ^c	4.2 ^{ab}	4.4 ^{ab}	3.6 ^c	4.6 ^{ab}	4.8 ^a	0.20	ns	***
Lungs	3.9 ^c	4.6^{abc}	5.1 ^a	4.0 ^{bc}	4.8 ^{ab}	4.6^{abc}	4.0 ^{bc}	4.7 ^{ab}	5.3 ^a	0.27	ns	**
Kidney	0.6 ^b	0.6 ^b	0.9 ^a	0.6 ^b	0.6 ^b	0.8 ^a	0.5 ^b	0.6 ^b	0.9 ^a	0.04	ns	***
Spleen	0.6 ^{cd}	0.7 ^{bc}	0.9 ^a	0.6 ^{cd}	0.7 ^{bc}	0.8^{ab}	0.5 ^d	0.7^{bc}	0.7 ^{bc}	0.04	ns	***
Empty intestines	10.1 ^c	11.1 ^{bc}	11.2 ^{bc}	10.1 ^c	11.0 ^{bc}	12.0 ^{ab}	10.6 ^c	11.8 ^{ab}	12.5 ^a	0.44	ns	***
Empty Stomach	8.3 ^{ab}	9.2 ^a	7.8 ^b	8.7 ^{ab}	8.8 ^a	8.5 ^{ab}	9.0 ^a	9.3 ^a	8.8 ^a	0.40	ns	**
Kidney fat	0.6 ^d	0.8 ^{cd}	1.1^{abc}	0.9^{bcd}	0.7 ^d	1.2 ^{ab}	0.7^d	0.9^{bc}	1.4 ^a	0.13	ns	***
Digestive tract fat	1.8 ^c	2.3 ^{bc}	3.1 ^{ab}	2.2 ^{bc}	2.6 ^{ab}	3.5 ^a	2.2 ^{bc}	2.5 ^b	3.4 ^{ab}	0.27	ns	***
Total internal fat	2.7 ^b	3.3 ^b	4.3 ^a	3.1 ^b	3.1 ^b	4.7 ^a	3.0 ^b	3.4 ^b	4.7 ^a	0.39	ns	***
Scrotal fat	0.3 ^d	0.4^{cd}	0.6 ^{ab}	0.4^{cd}	0.5 ^b	0.7 ^a	0.3 ^d	0.3 ^d	0.5 ^{bc}	0.05	**	***

Table 3.5: Least square means showing effects of genotype and feeding system on Slaughter characteristics

ANK-Pure Ankole, AXB-Ankole-Boran crossbred, AXF-Ankole-Friesian crossbreds, T1-Sole grazing, T2-Grazing plus concentrate supplement, T3-Feedlot finishing, Gen-Genotype, FS-Feeding system, S HCD – Hot Carcass dressing percentage; abc Means with different superscripts within a row are different (*P*<0.05); ***P*<0.001; ****P*<0.0001; ns-not significant; ¥ - Genotype x Feeding system interaction effects were not significant and not shown.

3.3.5. Gross margin analysis

Least square means of variable costs, total revenue, gross margin and marginal revenue are presented in Table 3.6. Genotype effects were not significant on all costs and revenue parameters measured. Feeding system affected (P < 0.05) all parameters except purchasing cost of bulls and marginal revenue. Cost of feeding was higher (P < 0.001) at the feedlot (T3) than in supplementation of grazing (T2) and sole grazing (T1). Veterinary costs were higher (P < 0.001) and similar in T2 and T3 than T1 for all genotypes, meanwhile, cost of management was higher (P < 0.001) at the feedlot compared to the supplementation of grazing compared to sole grazing. Highest total variable cost (Ush, 397,100) was observed with the Ankole x Boran crosses under feedlot while lowest total variable cost occurred with the Ankole x Friesian crosses under sole grazing.

Total revenue was higher (P < 0.01) and similar in supplementation of grazing and feedlot finishing compared to sole grazing except in the Ankole x Boran crosses were total revenue was similar in all feeding systems. The highest total revenue (Ush. 616,600) was obtained in the Ankole x Friesian crosses at the feedlot while lowest revenue (Ush. 479,000) also occurred in the same genotype under sole grazing. Gross margin was generally higher in solely grazing bulls but similar to supplementation of grazing in all genotypes except Ankole x Boran crosses. Feedlot finishing had the lowest gross margins but similar to supplementation of grazing.

		ANK			AXB			AXF			Significance	
	T1	T2	T3	T1	T2	T3	T1	T2	T3	SEM	Gen	FS
Purchasing cost [*]	187.3	186.7	187.5	205.2	205.4	205.0	184.0	185.8	184.6	15.3	ns	ns
Feed costs	13.3 ^c	136.6 ^b	166.0 ^a	13.3 ^c	143.8 ^b	163.6 ^a	13.3 ^c	139.5 ^b	169.7 ^a	4.3	ns	***
Veterinary costs	3.4 ^a	3.4 ^a	2.2 ^b	3.5 ^a	3.5 ^a	2.4 ^b	3.3 ^a	3.4 ^a	2.3 ^b	0.1	ns	***
Management cost	2.5 ^c	7.5 ^b	11.3 ^a	2.5 ^c	7.5 ^b	11.3 ^a	2.5 ^c	7.5 ^b	11.3 ^a	0.0	ns	***
Marketing costs	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	na	na	na
Total variable costs	208.2 ^c	349.1 ^b	382.0 ^{ab}	226.2 ^c	375.1 ^{ab}	397.1 ^a	204.9 ^c	351.2 ^{ab}	382.7 ^{ab}	18.3	ns	* * *
Total revenue	483.6 ^b	589.7 ^a	577.0 ^a	545.3 ^{ab}	597.7 ^a	609.7 ^a	479.0 ^b	567.7 ^{ab}	616.6 ^a	34.3	ns	**
Gross margin	275.4 ^{ab}	240.5 ^{bc}	195.0 ^c	319.1 ^a	222.5 ^{bc}	212.5 ^{bc}	274.2 ^{ab}	216.5 ^{bc}	233.9 ^{bc}	21.6	ns	***
Marginal revenue ^Ø	na	106.1	93.4	na	52.3	64.4	na	88.6	137.6	27.1	ns	ns

Table 3.6: Least square means for variable costs, total revenue, gross margins and marginal revenues per bull in the different feeding systems ('000 Uganda shillings)[#]

[#]-US\$ 1 = UGX 1,850 at the time of study; *Purchasing cost of bulls; ^{abc}Means with different superscripts within a row are different (P < 0.05); ****-(P < 0.001); **-(P < 0.01); ns-not significant; na-not applicable; ANK-Pure Ankole, AXB-Ankole-Boran crossbred, AXF-Ankole-Friesian crossbreds, T1-Sole grazing, T2-Grazing plus concentrate supplement, T3-Feedlot finishing, Gen-Genotype, FS-Feeding system, ⁰Marginal revenue was computed as the additional revenue generated from change from sole grazing (T1) to supplementation of grazing (T2) and feedlot finishing (T3).

3.4. Discussion

3.4.1. Genotype effects on feed utilisation

Concentrate dry matter intake was higher in the AXB and AXF crossbreds than the pure Ankole bulls. Dry matter (DM) intake in ruminants is known to be associated with various factors. However, Preston and Leng (1987) noted that supplement intake varies considerably between individual animals ranging from completely nothing to considerable amounts. They further added that different animals also take different duration of time before getting used to eating supplemental feeds. But this study demonstrates that supplemental feed intake is higher in crossbreds than in the pure Ankole cattle. This could be an indication of variations in adaptability to intensive management and also level of nutrient demands between the different genotypes. Forbes (2007) listed such factors as stomach distension, plasma glucose concentration, body temperature, plasma amino acid concentration or inherent and preparatory feed properties as regulators of feed intake in ruminants.

The lower concentrate DM intake of Ankole bulls could have resulted from lower substitution effects of concentrates on their pasture intake as compared to AXB and AXF. This could have resulted in their higher intake of forage resulting in higher rumen distension hence limiting concentrate intake. This is based on the argument that physical regulation of feed intake in the tropics is a more pronounced phenomenon (Madsen *et al.*, 1997). Much as not measured in this study, an overall reluctance of Ankole bulls in entering the pens for concentrate in the evening was observed compared to the AXB and AXF which rushed in for concentrate on return from grazing. This could further explain the substitution effect in the different genotypes. This is however, subject to investigation since herbage intake was not measured in this study. However, the higher efficiency of feed utilisation of the Ankole bulls which was also statistically different from AXF could also be a revelation of their better adaptability to grazing based feeding systems in their natural environment. Therefore, basing on feed intake and efficiency of feed utilisation as major parameters of productivity, it can be argued that Ankole cattle present a better opportunity for improved productivity under supplementation of grazing with concentrate.

Dry matter intake of bulls at the feedlot was higher in the pure Ankole cattle and the Friesian crossbred than the Boran crossbred (Fig. 3.2A). Dry matter intake of feedlot bulls is said to be regulated by total energy intake and hence, animals with lower energy requirements will

subsequently consume less (Forbes, 2007). Preston and Leng (1987) also indicated that, in the absence of nutritional and environmental constraints, potential feed intake is determined by the animal's genetic potential. The authors observed a direct relationship between the amount of feed consumed and the productivity of the animal. These arguments are supported by the numerically higher growth rates of the Ankole and Ankole-Friesian crossbreds at the feedlot than the Boran crossbreds.

The crossbreds with Friesian were more efficient in feed utilisation at the feedlot than the pure Ankole and the crossbreds with Boran. Factors affecting feed efficiency are noted to include digestion of feed, heat increment, protein turnover and overall tissue metabolism. Additional factors also include temperament², feeding behaviour and activity, body composition and rate of gain and body weight (Johnson et al., 2003; Richardson and Herd, 2004). The higher feed conversion efficiency of the Friesian crossbreds could, therefore, be attributed to their docile temperament resulting in higher growth rate although other studies have shown some independence of feed efficiency from rate of gain and body weight (Nkurumah et al., 2007a). But in accordance with the reports of Nkurumah et al. (2007b) feeding behaviour and temperament could have been some of the major factors that influenced feed efficiency in this study. Temperament is one of the distinct factors that easily separate the Friesian crossbreds from the pure Ankole and the Boran crossbreds. The Friesian crossbreds though not investigated in the study had an observably better temperament than the pure Ankole and the Boran crossbreds which had a poorer temperament. Therefore, under fully intensive management, the Ankole-Friesian crossbreds and the pure Ankole cattle offer a better opportunity to increased beef production basing on feed utilisation at the feedlot observed in this study (Fig. 3.2C).

3.4.2. Blood metabolites

Glucose and lactate were higher in grazing animals than in animals at the feedlot. Highest values of the two metabolites were obtained in the ANK and AXB crossbred. However, the observed values for most of the measured metabolites met their optimal values for normal nutritional status of the animals (i.e. >2.5 mmol/L for glucose, <50 g/L for globulin, 61-81 g/l for total

 $^{^{2}}$ Temperament in this context is defined according to the definition of Burrow, 2001 as the mean flight speed of an animal i.e. the time taken (in hundredths of a second) for an animal to cover 1.7 m after leaving a weighing crush

protein, and less than 3.6 mmol/L for blood urea nitrogen). In the grazing bulls, albumin content was either below or close to the optimal value (>28 g/L) for normal body functioning (Grünwaldt *et al.*, 2005; Boonprong *et al.*, 2007). The lower albumin levels were possibly indicative of insufficiency of protein intake by grazing bulls.

Blood urea nitrogen which is a major indicator of nitrogen metabolism in ruminants was higher at the feedlot than in grazing and grazed and supplemented animals. This is consistent with the reports of Bunting *et al.* (1989) who showed that BUN concentration was higher in steers fed higher level of protein. It could therefore, be argued that, the low levels of BUN in grazing animals was a result of poor quality amino acid profile and proportion of BUN been recycled to the rumen to meet microbial requirements for nitrogen resulting in low levels in the blood. This recycling could have occurred at a slower rate in the feedlot animals due to sufficiency in dietary nitrogen of better quality.

It is, however, important to note here that much as effects of transportation and fasting were not investigated in this study, these two factors could have played major roles in the blood metabolites measured in this study.

3.4.3. Rumen environment characteristics

Rumen pH values of 7.2 - 7.4 observed in this study were higher than the normal pH range of 6.6 – 7.0 reported by Mouriňo *et al.* (2001). Following the time of collection of the rumen samples after slaughter, there is a higher chance that other factors such as fasting and transportation stress could have affected pH more than dietary treatments. A similar pH range was reported by Gregory *et al.* (2000) who evaluated effects of pre-slaughter treatment on physico-chemical properties of cattle digesta. The authors showed that pre-slaughter fasting favoured increased rumen pH. This could be attributed to increased saliva secretion that results in increased bicarbonate concentration in the rumen. There is also a possibility of reduced concentration of volatile fatty acids in the rumen due to fasting that leads to increased pH. However, of interest to note are the different diets under which lowest pH occurred, especially between the Boran and Friesian crossbreds. While lowest pH in the Boran crossbreds occurred under sole grazing, lowest pH in the Friesian crossbreds occurred under feedlot finishing. If the pre-slaughter management can be justified as a major cause for the variation in pH, it then implies that pre-

slaughter treatment effects vary between different systems of management and also different genotypes.

The observed acetate proportions were also lower than the most commonly reported range, although the reduction in acetate proportion resulting from concentrate intake was observed (Preston and Leng, 1987). Purely grazed and grazing animals that are supplemented had numerically higher acetate than feedlot animals. However, unlike in the Friesian crossbreds where highest molar proportion of acetate occurred under solely grazing conditions, highest molar proportion of acetate in pure Ankole and Boran crossbreds occurred under supplementation to grazing. Propionate was also higher in the feedlot animals than solely grazed and grazing animals that are supplemented. The reduced acetate levels associated with concentrate supplementation and the increased propionate was evident in reduction of acetate:propionate ratio at the feedlot. These observations are in agreement with the reports of Khalili (1993) and Khalili et al. (1993) who showed that propionate and butyrate production in the rumen increased with molasses supplementation. This was also in tandem with the reports of Bergman (1990) that diet can change the metabolic activities of the rumen microorganisms by providing new or different substrates and hence influencing the nature and quantities of fermentation products. Preston and Leng (1987) also noted the increase in propionate production as a result of feeding cereal grains in the diets of ruminants. The results further demonstrate that even after fasting and transportation, the molar proportion of propionate in concentrate fed animals still remained higher. Galyean et al. (1981) showed that proportion of propionate did not vary significantly in mature beef steers after 32 hours of fasting and transit. However, further investigation on the effects of supplemented and feedlot finishing on the rumen fermentation characteristics would enhance the understanding of feed utilisation by beef animals.

3.4.4. Growth characteristics

Within all genotypes, weight gain increased from purely grazing (T1) to grazing plus concentrate supplement (T2) and then the feedlot (T3). The AXF crossbreds, however, had higher growth rate than the pure Ankole (ANK) and the AXB bulls. Similar findings were reported by Mpairwe *et al.*, (2003) on performance improvement resulting from nutritional management. Faster growth rate of crossbreds (HolsteinxBoran) was also reported by Jenet *et al.* (2004) and Laswai *et al.* (2007) with Zebu x 50-87 Friesian/Ayrshire crossbreds. The higher growth rate of the AXF

could be attributed to the large frame and heavier mature size (Owens *et al.*, 1993; Burns *et al.*, 1997). Crouse *et al.* (1989) reported that growth rates of cattle of *Bos indicus* origin increased with increasing blood of *Bos taurus*. Variation in energy and protein retention between breeds are also part of the factors responsible for variation in body weight gain (Geay, 1984). Also associated with growth performance is temperament, which is said to reduce growth rate (Burrow & Dillon, 1997). This could have been one of the factors that lead to the lower growth rates of the Ankole-Boran crossbreds which notably had a poorer temperament even though temperament was not measured in the study.

The higher feed intake of the Ankole-Friesian crossbreds especially at the feedlot coupled with their better feed efficiency also contributed to their better growth rate. Studies on relationship of feed efficiency, performance and feeding behaviour have revealed a positive correlation between dry matter intake and growth rate (Nkrumah *et al.*, 2004; Nkrumah *et al.*, 2006). But, the lack of statistical difference between the ANK and AXF also reflects the fact that feed characteristics remain a major factor limiting the productivity of the Ankole cattle. Supplementation and feedlot finishing therefore offer an opportunity to improved beef production from indigenous genotype.

Improved growth performances of bulls resulting from intensive management have been widely reported. Of importance and much related to this study is the report of Kabi (2003) who noted that intensively fed young Ankole x Friesian bulls gained up to 800 g live body weight per day when fed maize stover and molasses basal diets in a feedlot. Several factors are associated with improved growth rates from intensive management. Apart from higher nutrients supplied to intensively fed animals, differences in utilisation of maintenance energy between intensively managed and extensively managed animals have been reported. Caton & Dhuyvetter (1997) reported that energy spent by extensively managed animals for chewing, ruminating and locomotion during grazing account for about 23 % of their total energy expenditure. Comparison of energy expenditure of grazing and housed sheep by Osuji (1974) also showed that the grazing sheep spent 30% more energy than housed sheep. It can, therefore, be argued that the lower growth rate of animals in T1 and T2 (Table 3.3) was associated with limited available of energy for growth. Furthermore, growth differences associated with feeding practices are also said to result from variations in volatile fatty acid composition, methane and carbondioxide production and heat increment. Concentrate feeding is noted to promote lower acetate to propionate ratio which is associated with faster growth rates and increased feed efficiency (Shaw *et al.*, 1960). A

reduced acetate:propionate ratio with concentrate intake was evident in this study. Acetate:propionate ratio was lowest with feedlot animals compared to grazing and supplemented animals and solely grazed animals. This therefore, possibly explains the higher growth rate of animals in the feedlot. This is further explained by the fact that acetate and butyrate are said to mainly provide energy for the activity of rumen wall while the extra is used for fat synthesis in adipose tissue. Meanwhile, propionate is noted to be taken up almost completely by the liver and used for glucose synthesis (Forbes, 2007) hence a direct source of energy for tissue development. Propionate is also known to have a sparing effect on the amino acids that would otherwise be used for glucogenesis activities and hence its direct association with tissue development. Therefore, feedlot finishing presents a greater opportunity for improved beef production in Uganda.

3.4.5. Slaughter characteristics

Genotype only affected, hide plus tail and feet of all the slaughter characteristics measured (Table 3.4). The lack of statistical difference between indigenous tropical cattle and their crossbreds on slaughter characteristics has been reported (Eltahir *et al.*, 2000a). However, the heavier head weights of ANK can be attributed to their larger horns (i.e. length of 80-150 cm and base circumference of 30-60 cm) (Huber *et al.*, 2008). The higher weights of hide plus tail of the ANK and AXB crossbreds is associated with the prominent dewlap and umbilical flap, typical to indigenous tropical cattle breeds. Cattle of tropical origin are also known to have thick hides as a protective mechanism against tick infestation and insect bites. However, the large frame size of the ANK and AXF crossbreds were not reflected in higher carcass yields as opposed to the reports of Du Plessis and Hoffman (2007) who noted that larger frames yield more carcasses. But, there is need to investigate other factors such as age and time spent at the feedlot as these are noted to be major contributors to carcass weight of feedlot animals (Swanepoel *et al.*, 1990).

Feeding system affected all the carcass and non-carcass components measured in all genotypes apart from hot carcass dressing percentage. Higher weights of components obtained in the feedlot than the supplementation of grazing and solely grazing system can be associated with higher nutrient intake and lower maintenance energy requirements. Buttery *et al.* (2005) noted quantity and quality of feed available as one of the major factors affecting nutrient partitioning in ruminants. Much as various studies have attributed differences in organ development as an

adaptation to handle higher levels of roughage in diets (McClure *et al.*, 1995; Hata *et al.*, 2005), the current study did not seem to indicate variation in organ size with feeding system. This could imply that pasture quality was adequate for the grazing bulls, although, feedlot bulls tended to have numerically lower stomach weights. Of significance to note here was the higher internal fat deposition in the feedlot bulls. This implies that supplied nutrients met all their maintenance and production requirements. This is because fats are noted to be the least priority in nutrient partitioning in ruminants (Buttery *et al.* (2005). Further investigation into the optimal nutrient requirements of the beef animals is necessary if productive efficiency of the animals is to be achieved.

3.4.6. Gross margins

Genotype did not affect the variable costs, total revenue and gross margins (Table 3.6). This is an indication that the Ankole bulls do not differ from their crossbreds in terms of gross margins in beef production. However, numerical values showed that the pure Ankole were more profitable genotype for beef production under supplementation of grazing while the crossbreds with Friesian were better suited for feedlot finishing. The lack of statistical difference in gross margins between the pure Ankole and its crossbreds especially with Friesian supports the argument by Strydom (2008) that the indigenous cattle actually have a potential for improved beef production. It is, therefore, imperative that selection and utilisation of the Ankole cattle for beef yields in Uganda. Meanwhile, the good performance of the crossbreds with Friesian under feedlot offers a vital opportunity for utilisation of the bull calves resulting from the faster growing dairy industry.

The variations in variable costs and revenue between feeding systems were expected due to the differences in variable input requirements. Higher total variable costs in feedlot finishing (T3) and supplementation of grazing (T2) are reflective of the higher costs associated with feeds and management. Although, veterinary costs were lower in T3, the differences were not higher enough to cause a major change in total variable costs. Higher variable costs associated with supplementation have also been reported by Mapiye *et al.* (2009). However, the similarity in total variable cost between supplementation of grazing and feedlot finishing reveals that, in the event of high cost of structural investment, supplementation of grazing offers the best alternative for improved beef production. The largely extensive beef farming community in Uganda can

therefore, benefit from this method of finishing. This is further confirmed by the similarity in total revenue, gross margin and marginal revenue accrued from feedlot finishing and supplementation of grazing. However, the numerically higher gross margins generated from sole grazing compared to supplementation of grazing and feedlot finishing warrants the need for beef pricing mechanisms that cater for the added value from feedlot finishing and supplementation of grazing.

Therefore, supplementation of grazing and feedlot finishing can considerably improve the total revenue and subsequently gross margins of beef production among the livestock keeping communities in Uganda. However, a more developed market structure where beef grading systems are well established and higher value is attached to beef from intensive production systems would augment the achievements from such interventions.

3.5. Conclusion and recommendations

- 1. The pure Ankole cattle have comparable potential for beef production as their crossbreds with Boran and Holstein Friesian under similar management. Their potential could be tapped to improve meat production in Uganda.
- Feedlot finishing and supplementation of grazing result in faster growth rates and higher meat yield than solely grazing feeding system and hence offer better opportunity for improved meat production.
- 3. Concentrate feeding results in improved blood metabolite and rumen fermentation characteristics which are indicative of improved efficiency of nutrient utilisation.
- 4. Higher revenue can be achieved from supplementation of grazing and feedlot finishing of Ankole bulls and their crossbreds with Boran and Friesian.
- 5. There is need for further evaluation of the productive potential of the Ankole cattle and their crossbreds for beef production. This can achieved through evaluation of factors such as age and duration of concentrate supplementation or feedlot finishing.
- 6. There is also need to further evaluate the utilisation of the different feed resources for improved meat production if optimal levels are to be achieved.
- 7. Ultimately, selection and utilisation of the Ankole cattle for higher meat yields would enhance their productive potential.

4.0 Growth and slaughter characteristics of grazing Mubende and Mubende x Boer goats supplemented with concentrates

4.1. Introduction

Goat production in Uganda is mainly limited to natural pastures and crop residues with tethering and herding as the major management practices (Ssewannyana *et al.*, 2004). Smallholder subsistence farmers own most of the 12.5 million goats in the country of which 0.2 million (i.e. 1.2%) are exotic (UBOS, 2009). The productivity of the animals is severely limited by seasonal fluctuations in quantity and quality of the available feed resources and relatively poor performance of the indigenous goat genotypes. Moreover, *ecto* and *endo* parasites and overall low input use also significantly affect productivity of goats in Uganda (Ssewannyana *et al.*, 2004).

Three genotypes including the Mubende goat, the Small East African (SEA) goat and the Kigezi dominate in the goat production systems (Nsubuga, 1996, UBOS, 2009). The Mubende goat is reportedly the large sized genotype with mature live body weight ranging from 35 - 40 kg while the SEA and the Kigezi goats have mature weights ranging from 20 - 25 and 25 - 30 kg, respectively. Attempts to improve the performance of the local goat genotypes through breeding and nutritional management have been made. The Boer goat from South Africa which now constitutes 79.1% of all exotic meat goat genotypes was imported to the country in a bid to improve the meat yielding potential of the indigenous goats (Nsubuga, 1996). An evaluation of Boer x Mubende crossbreds by Oluka *et al.* (2004) showed considerable growth performance improvement.

Efforts in nutritional management include, among others the studies of Okello *et al.* (2004) who evaluated the effects of different sources of supplement (i.e. maize bran, cotton seedcake and banana peelings) under *Pennisetum purpureum* based basal diets on performance of goats. The study found that supplementation with maize bran and cotton seedcake resulted in higher average daily gain (ADG) and empty body weights. A study by Katongole *et al.* (2009) on utilisation of market crop wastes showed a potential in these feed resources, especially sweet potato vines. Amidst these efforts, much has not changed from the existing extensive production systems that heavily rely on the local genotypes which subsist on range pastures.

However, there is an increasing stress on the existing resource base for extensive livestock production practices resulting from rapidly growing demand for livestock products. This is mainly attributed to increasing human population pressure, growing income of communities and urbanisation. Bouman *et al.* (2005) noted that, there is a general and gradual trend towards intensification of ruminant production practices due to the increasing demand for livestock products. Further iterating that intensification will come along with decreasing dependence on open range feeding and increasing use of concentrate feeds to supplement fodder. Blache *et al.* (2008) also concluded that the use of alternative feed stuffs for goat and sheep production is likely to increase because of the need to increase livestock production in the developing countries. The objective of this study was, therefore, to establish the potential of using locally available agro-industrial by-products for improved meat production from the Mubende goat and its crossbreds with Boer.

4.2. Materials and methods

4.2.1. Description of the study location

The study was conducted in Kiruhura district found in South Western Uganda about 300 km from the capital Kampala. Kiruhura district lies within the cattle corridor of Uganda at an altitude of 1300m and latitudes 1 ° 0" 0' North and 031⁰ 04" 34' East. The area receives a total mean annual rainfall ranging from 800 - 1233 mm. The total rainfall for 2007 was 977 mm. Annual temperatures vary between 28 °C maximum and 16 °C minimum. Major grass species in the area include *Brachiaria, Cymbopogon, Themeda, Panicum, Chloris, Sporobolus* and *Laudetia* while *Acacia spp.* are the most common leguminous shrub species found in the area.

4.2.2. Experimental animals and treatments

A 2 X 3 factorial treatment structure was used to randomly allocate 96 castrate goats $(31.3\pm2.2 \text{ kg initial weight})$; 48 pure Mubende (MDE), 48 Mubende-Boer (MXB) crossbreds aged between 9 and 15 months, to three dietary treatments. All goats were purchased from Ruhengyere, a government ranch found in Mbarara district, South Western Uganda. Goats were stratified by weight into two groups of similar animals within genotypes. Correspondingly, goats were allocated randomly within weight groups to the three dietary treatments. Sixteen animals per genotype were assigned to each dietary treatment according to the weight groups. Goats in each weight group were fed in groups of eight per pen (4x3m). Two pens per treatment formed the experimental unit for data on concentrate dry matter

intake. The dietary treatments included, GZ in which animals were solely grazing as control, MCC where grazing animals were supplemented with concentrate without molasses and treat MCM where grazing animals were supplemented with concentrate containing molasses. Detail of the physical composition of concentrates is presented in Table 4.1.

4.2.3. Animal feeding and management

Animals were given a two weeks adaptation period within which they were treated for internal parasites. External parasites were controlled through weekly spraying throughout the trial period using deltamethrin (decatix). Animals were released to graze at 10:00 hours and returned in to pens by 17:00 hours. Concentrates were offered twice in a day; early in the morning before being released for grazing and in the evening at 17:00 hours after return from grazing. Daily concentrate offer included an additional 10% of previous day's intake to ensure *ad libitum* voluntary intake. Free access was allowed to water and rock salt within pens for MCC and MCM; and in shades for GZ. The trial lasted for 90 days excluding two weeks of adaptation.

4.2.4. Feed intake and body weight measurements

Daily concentrate offer and refusal weights were taken every morning per pen to determine concentrate dry matter (DM) intake. Representative concentrate samples and refusals were taken weekly and each pooled for chemical analysis. Pasture DM intake was not determined; nevertheless, monthly pasture samples were taken and pooled for chemical analysis. The formula below was used to determine the efficiency of concentrate utilization in MCC and MCM. Feed costs were also taken to establish the additional cost of feeding concentrate.

$$FE = \frac{Concentrate DM \text{ int } ake (kg \ day^{-1})}{ADG_{MCC \ or MCM} \ (kg) - ADG_{GZ} \ (kg)}$$

Where: FE = Efficiency of concentrate utilisation

 ADG_{GZ} = Average daily live body weight gain of goats in GZ

 $ADG_{MCC \text{ or } MCM} = Average daily live body weight gain of goats in MCC or MCM.$

Initial body weights of goats were determined by two consecutive days of weighing and subsequent weights were taken every 14 days. All weights were taken before a day's morning offer of feeds. Average daily body weight gain was determined as a proportion of total weight

change to the feeding period of 90 days. Plate 4.1 shows animals during one of the times of weighing.



Plate 4.1: Goats awaiting weighing

4.2.5. Blood sampling and analysis

Blood samples were taken at slaughter for analysis of blood metabolites. About 10ml samples were taken from jugular vein puncture using plastic syringes. About 3 ml samples were transfered in heparinised vacutainers containing ethylenediaminetetraacetic acid (EDTA) as anticoagulant. Samples in the vacutainers were temporarily stored in an ice-box packed with dry ice and transferred within one hour for analysis of blood plasma using commercial kits for glucose (Nerono diagnostic reagents, Nicosia, Cyprus) and lactate (DiaSys diagnostic systems GmbH, Holzheim, German) in a Cobas Integra 400/700/800 analyzer (Roche diagnostics GmbH, D-68298 Mannheim, USA). Part of the blood samples collected were stored in non-heparinised vacutainers and were allowed to clot; serum was extracted and stored in plastic vials at a temperature of below -18 ^oC until analysis for blood urea nitrogen (BUN), total protein (TP), albumin and globulin. The serum samples were also analyzed using the Cobas Integra 400/700/800 analyzer.

4.2.6. Measurements at slaughter

At the end of the feeding period, 10 goats per treatment were selected by weight and slaughtered in two batches of 30 animals each. Goats were transported for about 10 hours to a commercial abattoir located 300 km from the ranch and were slaughtered after an overnight fasting. Each goat was weighed before slaughter to determine the slaughter weight. Hot carcass weights were taken immediately after removal of non-carcass components. Dressing

percentage was computed as a proportion of the hot carcass weight to the slaughter weight. Weights of head, skin together with tail and feet, heart, lungs with trachea, kidney without fat, liver, empty stomach (rumen, reticulum, omasum and abomasum) and empty intestines large intestines) with caecum were taken and recorded as non-carcass (small and components. Omental fat, mesenteric fat, kidney fat, pericardial fat and scrotal fat were also weighed and recorded. Kidney fat and pericardial fat were summed into pluck fat while omental and mesenteric fat were summed as digestive tract fat. Total internal fat was computed as the sum of the digestive tract fat and the pluck fat.

4.2.7. Chemical analysis of feeds

Concentrate and pasture samples were analysed for dry matter (DM), crude protein (CP), ether extracts (EE), calcium (Ca) and phosphorous (P) and total ash according to the procedures of AOAC (1990). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analysed by the procedures of Van Soest et al. (1991). Gross energy (GE) was analysed using the bomb calorimeter (GALLENKAMP Autobomb, UK). Physical and chemical composition of feeds is presented in Table 4.1.

Table 4.1: Physical and chemical composition of feeds										
	MCC	MCM	Pasture							
Ingredients (g/kg)										
Maize bran	700.0	580.0	-							
Cotton seed cake	300.0	220.0	-							
Molasses	-	200.0	-							
Chemical components										
Dry matter	890.0	870.0	450.0							
Crude protein	173.0	164.0	91.0							
Ether extracts	82.0	86.0	9.8							
Neutral detergent fibre	517.0	377.0	558.0							
Acid detergent fibre	108.0	107.0	346.0							
Acid detergent lignin	27.0	101.0	109.0							
Ash	76.0	91.0	86.0							
Calcium	1.0	0.9	6.8							
Phosphorus	10.5	11.5	4.7							
Gross energy (MJ/kg DM)	16.4	16.6	15.3							

e e

4.2.8. Statistical analysis

Data was analyzed using the general linear model (GLM) procedures of Statistical Analysis Systems (SAS, 2003). Factors included in the model were genotype, diet and genotype and diet interactions in a factorial design. Initial weight was used as a covariate for feed utilization parameters. The least square means generated were separated using standard error of the mean and the probability of difference option.

4.3. Results

4.3.1. Feed utilisation and growth of goats

Genotype and dietary effects on concentrate DM utilization, growth and cost of feeding are presented in Table 4.2. There were significant genotype (P<0.001) and dietary (P<0.001) effects on DM intake and feed efficiency of goats. Genotype and diet interactions were not significant for daily dry matter intake and total dry matter intake but significant for feed efficiency (P<0.001). The crossbreds had higher (P<0.001) concentrate DM intake compared to the Mubende goats in both MCC and MCM. Supplementation with concentrate without molasses resulted in higher (P<0.001) DM intake in both genotypes. Most efficient concentrate DM utilisation was seen in the pure Mubende (P<0.001) on MCM. But feed efficiency was higher (P<0.001) in MCM than MCC for the crossbreds.

Additional cost of concentrate feeding was higher in MCC goats than MCM goats in both genotypes. Lowest cost of feed per unit weight change was obtained in MDE under MCM, yet the highest feed cost per weight gain was observed in the same genotype under MCC.

Live weight changes were affected by genotype (P < 0.01) and diet (P < 0.001) but not genotype and diet interactions (Table 4.2). Except for the crossbreds in MCC which had higher weight changes; growth rates between MDE and crossbreds were comparable. Supplementation resulted in higher (P < 0.001) weight changes regardless of the type of concentrate. Average daily live weight gain of supplemented goats was twice the ADG of their grazing counterparts in both concentrates.

Average daily gain declined with time of the trial in solely grazed animals (Fig. 4.1A) unlike in MCC (Fig. 4.1B) and MCM (Fig. 4.1C) where average daily gain increased from the first to the second month. By the third month, growth rate was reducing in all genotypes.

Table 4.2: Least square means showing genotype and dietary effects on concentrate DM intake, growth and cost of feeding concentrate

Parameters		MDE			MX	KB		Significance		
	GZ	MCC	MCM	GZ	MCC	MCM	SE	Gen	Diet	Gen*Diet
Concentrate dry ma	atter utili	zation								
DMI [§] (kg/day)	-	1.4 ^c	1.2 ^d	-	1.6 ^a	1.5 ^b	0.03	***	***	ns
TDMI [£] (kg/90 days)	-	123 ^c	106 ^d	-	147 ^a	131 ^b	2.4	***	***	ns
FE ^ø (Kg DM/kg LW	G [#] /)-	27.6 ^a	19.9 ^d	-	22.5 ^c	25.7 ^b	0.59	***	***	***
Live body weight ch	anges (k	g)								
Initial WT	30.3 ^{ab}	28.6 ^b	28.8 ^b	32.8 ^a	31.3 ^{ab}	31.8 ^{ab}	1.3	*	ns	ns
Final WT	34.2 ^c	37.8 ^{bc}	37.9 ^{bc}	37.4 ^c	42.8 ^a	42.2 ^{ab}	1.7	**	**	ns
Weight gain	3.9 ^d	8.1 ^c	9.0 ^{bc}	4.6 ^d	11.6 ^a	10.4 ^{ab}	0.85	**	***	ns
Average daily gain	0.04 ^c	0.09 ^b	0.10 ^b	0.05 ^c	0.13 ^a	0.12 ^{ab}	0.009	**	***	ns
Cost of supplement	feeding (UGX [¢])/go	at							
Feed cost per day	-	407	314	-	500	389	-	-	-	-
Feed cost/kg WC^{4}	-	8,325	5,365	-	6,660	7,030	-	-	-	-
Feed cost (90 days)	-	36,075	27,750	-	44,400	35,520	-	-	-	-

Values in a row with different superscripts differ significantly (P < 0.05); MDE-Pure Mubende, Mubende-Boer crossbreds, [§]DMI – Dry matter intake; GZ-Sole grazing, Grazing plus concentrate without molasses, Grazing plus concentrate with molasses, [£]TDMI – Total dry matter intake; [°]FE – Efficiency of feed utilisation; [#]LWG – Live weight gain; [§]WC – weight change; [¢]UGX – Uganda shillings; ns – not significant; SE – Standard error of the mean; ***P < 0.001; **P < 0.05; [§]US\$ 1 = Ush. 1850



Figure 4.1 Variation of average daily live weight gain with time for; grazing (A), grazing supplemented with concentrate without molasses (B) and grazing supplementd with concentrate containing molasses (C).

4.3.2. Blood metabolite

Genotype differences were not detected for all blood metabolites measured (Table 4.3). Only albumin (P < 0.001) and blood urea nitrogen (P < 0.001) were affected by dietary treatment. Concentrate supplementation resulted in higher blood albumin in both the crossbreds than the pure Mubende. Blood urea nitrogen followed a similar trend among the concentrate supplemented goats. No significant dietary effects were obtained for glucose, lactate, total protein and globulin.

4.3.3. Slaughter characteristics

Genotype and dietary effects on carcass and non-carcass characteristics are presented in Table 4.4. The supplemented goats had higher slaughter weight (P < 0.01) and hot carcass weight (P < 0.001) than the control treatment irrespective of genotype. There were no genotype effects on hot carcass dressing percentage. Similarly, genotype and diet interactions were not significant on all slaughter parameters measured. Regardless of the concentrate, higher slaughter weight (P < 0.01), hot carcass weight (P < 0.001) and hot carcass dressing percentage (P < 0.001) were obtained in the supplemented goats both in MDE and MXB. Among the non-carcass components measured, significant genotype effects were observed on: head (P < 0.001); skin with feet and tail (P < 0.001); liver (P < 0.01); lungs (P < 0.05); kidney (P < 0.01); spleen (P < 0.05); and empty stomach (P < 0.05). The crossbreds had higher non-carcass components than the pure Mubende goats.

Significant dietary treatment effects were obtained on; liver (P < 0.05), lungs (P < 0.01), spleen (P < 0.05), pluck fat (P < 0.01), digestive tract fat (P < 0.001), total internal fat (P < 0.001) and scrotal fat (P < 0.001). Concentrate supplemented goats had higher weights of non-carcass components. Internal fats were more than two times higher in concentrate supplemented goats than grazing goats.

	MDE			MXB				Significance			
Parameter	GZ	MCC	MCM	GZ	MCC	MCM	SED	Gen	Diet	Gen*Diet	
Blood metabolites											
Glucose (mmol/L)	5.9	6.3	5.7	5.9	5.2	5.5	0.7	ns	ns	ns	
Lactate (mmol/L)	3.3	4.0	3.6	3.1	2.9	4.3	0.8	ns	ns	ns	
Total protein (g/L)	76.4 ^b	84.1 ^a	78.8 ^{ab}	79.6 ^{ab}	74.2 ^b	77.7 ^b	2.7	ns	ns	ns	
Albumin (g/L)	32.9 ^c	33.8 ^{bc}	34.6 ^{ab}	33.3 ^{bc}	36.1 ^a	35.8 ^a	0.8	ns	***	ns	
Globulin (g/L)	43.5	50.3	44.6	46.3	38	41.8	2.7	ns	ns	ns	
BUN (mmol/L)	4.3 ^b	4.4 ^b	5.3 ^{ab}	4.9 ^b	4.4 ^b	6.0 ^a	0.4	ns	***	ns	

Table 4.3: Least square means showing effects of genotype and diet on blood metabolite

Least squares means within a row with different superscripts differ significantly (P < 0.05); MDE-Pure Mubende, Mubende-Boer crossbreds, [§]DMI – Dry matter intake; GZ-Sole grazing, Grazing plus concentrate without molasses, Grazing plus concentrate with molasses, ns – not significant; SE – Standard error of the mean; ***P < 0.001; **P < 0.01; *P < 0.05.

		MDE			MXB		Significance levels			
	GZ	MCC	MCM	GZ	MCC	MCM	SE	Gen	Diet	
Slaughter weight (kg)	34.6 ^d	37.9 ^{bc}	37.7 ^{bcd}	37.5 ^{cd}	42.8 ^a	41.0 ^{ab}	1.15	**	**	
Hot carcass weight (kg)	17.4 ^d	20.9 ^b	20.8 ^b	19.2 ^c	23.0 ^a	21.7 ^{ab}	0.46	***	***	
HCD [#] (%).	47.2 ^b	52.2 ^a	50.9 ^a	47.6 ^b	50.4 ^a	50.7 ^a	0.77	ns	***	
Non-carcass component	ts (kg)									
Head	2.1 ^b	2.1 ^b	2.2 ^b	2.4 ^a	2.5 ^a	2.4 ^a	0.07	***	ns	
Skin, feet and tail	3.9 ^b	3.8 ^b	4.0 ^b	4.4 ^a	4.5 ^a	4.3 ^a	0.12	***	ns	
Heart	0.19	0.23	0.24	0.25	0.27	0.23	0.026	ns	ns	
Liver	0.7 ^b	0.8^{ab}	0.8^{ab}	0.8^{ab}	0.9 ^a	0.9 ^a	0.04	**	*	
Lungs	0.56 ^c	0.67 ^a	0.63 ^{bc}	0.64 ^b	0.71^{a}	0.64 ^b	0.024	*	**	
Kidney	0.11 ^b	0.12 ^{ab}	0.13 ^{ab}	0.13 ^{ab}	0.14 ^a	0.15 ^a	0.011	**	ns	
Spleen	0.08 ^b	0.09 ^b	0.10 ^{ab}	0.09 ^b	0.11 ^a	0.10 ^{ab}	0.007	*	*	
Empty intestines	1.5 ^b	2.0 ^a	2.0 ^a	1.8 ^{ab}	2.2 ^a	2.1 ^a	0.21	ns	ns	
Empty stomach	1.3 ^b	1.3 ^b	1.3 ^b	1.5 ^a	1.4 ^{ab}	1.4 ^{ab}	0.06	**	ns	
Internal fat										
Pluck	0.2 ^b	0.5^{ab}	0.6 ^a	0.2^{b}	0.6 ^a	0.6 ^a	0.10	ns	**	
Digestive tract	1.0 ^b	2.1 ^a	2.1 ^a	0.8^{b}	2.3 ^a	1.7 ^a	0.23	ns	***	
Total	1.2 ^b	2.6 ^a	2.8 ^a	1.0 ^b	2.9 ^a	2.3 ^a	0.30	ns	***	
Scrotal fat	0.11 ^b	0.20 ^a	0.20 ^a	0.10 ^b	0.20 ^a	0.17 ^a	0.016	ns	***	

Table 4.4: Least square means showing genotype and dietary effects on carcass and non-carcass components

Least squares means within a row with different superscripts differ significantly (P < 0.05); MDE-Pure Mubende, Mubende-Boer crossbreds, [§]DMI – Dry matter intake; GZ-Sole grazing, Grazing plus concentrate with molasses, Grazing plus concentrate with molasses, n= not significant; SE – Standard error of the mean; ***P < 0.001; *P < 0.05, [#]HCD – Hot carcass dressing percentage.

4.4. Discussion

4.4.1. Concentrate DM utilisation

Although many factors are known to affect voluntary dry matter (DM) intake in ruminants, this study has demonstrated that higher DM intake by Mubende goats and their crossbreds is associated with higher levels of performance. The higher DM intake of the crossbreds (MXB) is in accordance with their faster growth rate compared to the pure Mubende (MDE). Preston and Leng (1987) noted that in the absence of environmental and nutritional constraints, feed intake is determined by genetic potential of animal for production. Forbes (2008) also reported that DM intake in ruminants is regulated by the requirements of individual animals. Generally, the higher DM intake of the crossbreds observed in this study is consistent with the findings of Cameron *et al.* (2001) who showed a higher DM intake of Boer x Spanish and Boer x Angora crossbreds over pure Spanish goats. While the crossbreds had better live weight gain, most efficient concentrate utilisation was observed in the indigenous Mubende goats. This superior feed efficiency observed among the Mubende goats compared to its crossbred counterparts suggests need for their conservation and improvement as a meat-goat breed.

Variation in DM intake as affected by concentrate supplementation revealed the importance of by-pass nutrients in improving feed intake and subsequently nutrient utilisation (Preston and Leng, 1987). This was expressed by the higher DM intake of the concentrate containing higher level of cotton seedcake which is a major source of by-pass protein (Peacock, 1996). Similar findings were obtained by Okello *et al.* (2004) and Negesse *et al.* (2008). Burns *et al.* (2005) also reported a linear increase in DM intake of alfalfa hay with increasing levels of crude protein in Spanish x Boer crossbreds.

However, the higher feed efficiency of goats fed diet containing molasses shows the importance of non-structural carbohydrates in diets of goats. Peacock (1996) indicated that molasses is a useful source of energy for improving rumen fermentation characteristics in goats. Coupled with the fact that goats are selective to succulent plant parts, there is therefore, an indication that non-structural carbohydrates could offer a major alternative to improving the performance of grazing goats. This also offers an opportunity for lower cost supplementation strategy as the higher efficiency of goats under the molasses containing diet was translated into lower cost of feeding concentrate. However, establishing the balance

between by-pass protein and the level of non-structural carbohydrate sources for optimum performance of meat goats needs to be evaluated.

4.4.2. Growth characteristics

The differences in growth performance of goats reflect variations in genotype potential and levels of nutrient intake. The higher growth rate of MXB crossbreds shows the genetic superiority of the Boer goat over the pure Mubende goat. This finding is in line with the studies of Oluka *et al.* (2004). Various other studies have also showed the superior growth rate of the Boer goat genotype when crossbred with indigenous goats (Cameron *et al.*, 2001; Negesse *et al.*, 2008).

Nevertheless, the lack of statistical difference between MCM supplemented MXB and the MDE reveals the underlying potential in the pure Mubende goat as a meat-goat breed. This is further demonstrated by their better feed efficiency under MCM. The similar growth trends of the two genotypes also showed the possible closeness in their growth and meat yielding potential.

Growth differences of goats resulting from dietary treatment can be attributed to variations in levels of nutrient intake as similar trends were observed in both genotypes. Increasing growth rates from higher levels of nutrient intake have been reported (Okello et al., 2004; Ben Salem and Smith, 2008; Negesse et al., 2008; Mushi et al., 2009a). Preston and Leng (1987) showed that the metabolites needed for improved productivity of ruminants are; oxidative energy in form of acetate and butyrate and glucogenic propionate. Increased production of these metabolites especially propionate with increasing amounts of concentrates in ruminant diets has been reported by Bergman (1990) who noted that higher growth performance rates of ruminants were attributable to higher propionate production. It is, therefore, possible that, the faster growth rate of concentrate supplemented goats partly resulted from the higher production of these metabolites in the rumen. Meanwhile, the growth rates of the grazing goats (40 g/day for MDE and 50 g/day for MXB) were comparable to those reported before (Oluka et al., 2004; Ssewaanyana et al., 2004). The wide growth performance difference between the grazing and supplemented goats calls for the need to establish the optimal levels at which the supplements can be used for more efficient and less costly goats meat production strategies.

4.4.3. Blood metabolites

Genotype effects were not significant on all blood metabolites evaluated, while dietary treatment affected only albumin and blood urea nitrogen (BUN) (Table 4.4). The similar blood metabolic profile of the two goat genotypes concur with the report of Sahlu *et al.* (1993) who observed no differences in the blood metabolites of Nubian, Alpine and Angora goats. This could be attributed to the homeostatic regulation of these metabolites by the liver. Sahlu *et al.* (1993) also reported that dietary treatment did not affect total protein and glucose levels in the above stated goat genotypes. This likely demonstrates that there is no considerable difference in the metabolic profile of different goat genotypes under similar environmental management.

Meanwhile, observed differences in albumin and blood urea nitrogen have been reported elsewhere (Hermeyer and Martens, 1980; Sahlu *et al.*, 1993). These authors observed that blood urea nitrogen increases with dietary protein intake and that urea concentration in blood is positively correlated to nitrogen intake. Bergman (1979) also observed that previous dietary protein intake determines the extent of catabolism in the liver which subsequently influences blood metabolite characteristics. Higher levels of serum albumin in the concentrate supplemented goats probably showed that; concentrates provided sufficient amounts of dietary protein to meet the demands of the animals, hence, protein was not limiting in their diet. However, the higher BUN levels in MCM goats suggested that more exchange of urea nitrogen could have occurred between blood and the gastrointestinal tract of goats in this group. Urea recycling is said to be positively related to the rate of apparent digestion of organic matter (Preston and Leng, 1987; Samanta *et al.*, 2003). Presence of molasses is likely to have influenced the rate of protein breakdown for microbial use in the rumen. This could be an indication that soluble carbohydrate is limiting in the feeding system with no molasses.

Nevertheless, timed investigation of the variations in blood metabolites with periods of varying growth rate and levels of nutrient intake would offer a better understanding of using blood metabolites to measure adequacy of nutrient supply to these goat genotypes

4.4.4. Slaughter characteristics

Numerically heavier carcasses of the crossbreds in the MCC diet revealed the greater potential of the Boer goat genotype for meat production although this advantage was over ruled by the similar dressing percentages of the two goat breeds. Shadnoush *et al.* (2001)

noted that the different carcass parts determine the relative merits of different breeds for meat production. However, the lack of difference in dressing percentage between MDE and MXB even at higher slaughter weights of MXB can be attributed to the higher non-carcass components, especially, head, skin, feet and tail of the MXB. Higher weights of non-carcass components and gut fill are known to reduce dressing percentage (Kadim *et al.*, 2004). The findings of this study did not show any significant comparative advantage of the MXB crossbreds over the pure Mubende goat for meat production under the conditions of this study.

Non-carcass components were heavier in the MXB than the MDE. The difference in head weights between the MDE and the MXB genotypes is associated with the relatively large horns of the Boer goat breeds. Also significantly heavier were; skin, tail and feet, liver, lungs, spleen and empty stomach which could be associated with the larger body size of the MXB genotype. Similar observations in non-carcass components were made by Cameron *et al.* (2001) in Boer x Spanish crossbreds.

The variation in carcass characteristics due to dietary treatment has a direct relationship with dietary nutrient intake in which case, energy and protein are of significant importance. Increased carcass weights resulting from higher protein and energy intake have been reported (Okello *et al.*, 1994; Mushi *et al.*, 2009a). Okello *et al.* (1994) reported higher carcass weights of Mubende goats fed cotton seedcake and maize bran. Meanwhile, increased carcass weights resulting from increased concentrate intake in Small East African x Norwegian crossbred goats has been reported (Mushi *et al.*, 2009a). Preston and Leng (1987) noted that, when ruminants are provided with unrestricted access to good quality feeds, they appear to be able to synthesise as much glucose as they need from propionate which has a direct relationship with increased growth rate.

Heart, liver, lungs, empty intestines, internal and scrotal fats were heavier in supplemented goats. Distribution of weights of different body parts in ruminants is said to be associated with nutrition level and age (Ryan *et* al., 1993). Higher weights of organs resulting from high levels of fibre intake in diets have been reported (Hata *et al.*, 2005). This is said to be an adaptation strategy to consume large amounts of fibre. However, this was not observed in this study, as organ weights of supplemented goats were heavier than the solely grazing goats. Possibly, the selective behaviour, typical of grazing goats lead to the goats consuming feeds with lower fibre. The heavier organ weights of the supplemented goats could, therefore, be attributed to higher protein and energy intake which provided sufficient nutrients for tissue
accretion. The high levels of internal fat deposition of the supplemented goats further confirmed the sufficiency of nutrients especially energy some of which was deposited as fats. Various studies have reported higher levels of fat deposition with increasing intake of these nutrients in goats' diets (Cameron *et al.*, 2001; Santos-Silva *et al.*, 2002; Mushi *et al.*, 2009b).

The internal fat deposition of more than 2 kg in the supplemented goats was, however, an indication of nutrient waste. Establishing the optimal level of nutrient utilisation by controlling level of nutrient supply, age of animal and time spent on feed could be necessary if optimal meat production levels have to be achieved.

4.5. Conclusions and recommendations

- Under similar conditions of grazing management and concentrate supplementation, the pure Mubende goats have a comparable meat production potential to their Boer crossbreds.
- Concentrate supplements formulated from agro-industrial by-products such as molasses and cotton seedcake considerably improve the meat production potential of the Mubende goat and its crossbreds with Boer.
- Further evaluation of the productive characteristics such age at finishing, duration on finishing diets would enhance the understanding of the Mubende goat and their crossbreds with the Boer for profitable meat production.

5.0 General conclusions and recommendations

Given the limited information on avenues for improved meat production in Uganda, this study has generated insights that can be relied on for a successful meat industry. The two studies, not only revealed the potential in the local animal genotypes but also the invaluable contribution the locally available feed resources can make to improved meat production through supplementation of grazing and feedlot finishing.

Study I proved the importance of the Ankole cattle in grazing based feeding systems for meat production. This was demonstrated by their higher efficiency of utilising supplementary concentrate under grazing. It is therefore, apparent that when appropriately managed, the Ankole cattle offer a great opportunity for improved meat production in Uganda.

An opportunity that lies in the utilisation of the Ankole x Friesian crossbred bulls for meat production under feedlot finishing was also revealed through study I. With the growing interest in dairy production and increased crossbreeding of the Ankole cattle with Friesian in Uganda, this finding offers a considerable prospect for better utilisation of the bull calves that are often rejected and sold prematurely by many dairy farmers.

The growth rates of the Ankole cattle and their crossbreds can be more than doubled when supplemented with concentrates and finished in feedlot. This implies that, the major limitation to the productivity of these animals is associated with the limited nutrient supply under grazing conditions but not a low genotypic potential for meat production.

Supplementation of grazing animals offers a lower investment opportunity for improved meat production as it resulted in similar variable costs and benefits as compared to feedlot finishing which is often associated with higher costs of investment. This finding demonstrates that grazing based finishing systems would offer a gate way for the often elusive higher yields of high quality meat in Uganda. The predominantly pasture based livestock keeping community could therefore benefit from supplementation of grazing if adopted.

Study II showed that pure Mubende goats can be relied on for improved goats meat production in Uganda. This was demonstrated by their lower feed intake but comparable growth rates and carcass yields to their Boer crossbreds. This shows that in the absence of crossbreeding, the Mubende goats are a potential meat goat genotype.

The two studies prove that, a high potential lies in the utilisation of agro-industrial byproducts like molasses, maize bran and cotton seedcake for improved meat production in Uganda, as evidenced by the improved performance of grazing and supplemented animals and the feedlot finished animals.

Optimal utilisation mechanisms for both the feed resources and the animal genotypes still remains a critical factor in determining the profitability of intensive management practices as the variable costs were high at the feedlot and in supplementation of grazing.

It is further recommended that production parameters such as different levels of feeding, duration of feeding and age of animals at finishing need to be evaluated to establish the most profitable level of quality meat production in Uganda.

It is also recommended that policies regarding the utilisation of agro-industrial feed resources such as molasses for production of local brew need to be revisited in favour of more productive uses such as feedlot finishing.

Following the commendable performance of the Ankole cattle and the Mubende goats for meat production, it is recommended that deliberate effort be instituted to establish a selective breeding programme for meat production traits with emphasise on the utilisation of these animals for meat production.

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Appendix 1: Computation of variable costs and revenues

1.1 Revenues

	Unit price (UGX/kg)				
Revenue					
Meat*	3500				
Intestines and stomach*	1700				
Skin*	1200				
Feet [#]	1000				
Head ^{\$}	5000				

*Prices are per kilogram of product, [#]Price per foot, ^{\$}Price per whole head of animal

1.2 Variable cost

1.2.1 Cost of purchasing animals

Animals were valued at UGX 1,000 per kg of live weight at the time of starting the experiment.

1.2.2.1 Concentrate (from least cost formulation)							
Ingredients	in diet	DM	MJ/kg DM	g/kg DM	DM	Ush/kg	
Maize bran	70	100	11.96	1.2	6.1	190	
Cotton seed cake	20	390	13.36	2	12	550	
Molasses	10	28.6	10.04	4	2.3	130	
Contribution to							
diet	100	150.86	12.048	1.64	6.9	256	
Animal							
requirements	100	140	11	5.25	3		

1.2.2 Feed costs

1.2.2.2 Grazing pasture

Cost of grazing pasture was estimated based on current rates of renting grazing land i.e UGX 40,000 per animal per year.

Hence four months (120 days of trial) per animal = $40000 \times 4/12 = 13,333$

1.2.2.3 Maize stover

Major costs of maize stover included buying 1 ha at UGX 30,000 and processing at UGX. 40,000. Yield of maize stover per ha was estimated at 5.8 tones based on estimates during feeding. Hence unit cost of maize stover = $30,000 + 40,000 (1/5.8 \times 1000) =$ UGX. 12/kg

1.2.3 Veterinary costs

Veterinary costs included deworming and dipping costs

Deworming cost was estimated based on current price of dewormer (Lefavas) and rate dosage per animal. Each animal was dewormed once. 0.5 litre of lefavas costed UGX. 15,000. Dosage was 2.5ml/kg live body weight.

Dipping cost was also estimate based on current price of accaricide (Tsetse tick) and amount of accaride and water an animal removes per dipping i.e. this was estimated at 2.5 litres per mature animal.

Item	Unit cost			
	(UGX/Animal)			
Movement permit	3,000			
Carcass processing charges	12,000			
Total	15,000			

1.2.4 Marketing cost