EFFECT OF SLAUGHTER WEIGHT ON MEAT PRODUCTION POTENTIAL OF WESTERN SUDAN BAGGARA CATTLE

By

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A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

In Animal Production

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October 2004
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Acknowledgements

Primarily my praise and thanks should be to Allah, the almighty, most gracious and most merciful who grant me the serenity, means, strength, and patience to conduct this article.

I am deeply indebted to my supervisor Prof. Salih Ahmed Babikir for his great valuable help and guidance with a sharp mind during this study, I am also grateful to his keen interest, patient assistant and invaluable advisement. Also I wish to acknowledge the assistant and moral support of my co-supervisor Prof Omer Abd elrahim Elkhidir.

I would like to express my gratitude to Dr. Muzzamil Atta for his valuable help and assistance in conducting statistical and computer data analysis. Thanks are also extended for Dr. Ikhlas Mohamed Nour head department of meat production in faculty of animal production university of Khartoum and the staff members of meat science laboratory with special appreciations for the efforts of Mr.Ahmed Elfadil.

Thank is due to research assistant Miss. Hiat Abdelhamid and Thuraia Mustafa for assisting on printing this thesis.

Finally I would like to express my gratitude to the Animal Resources Research Corporation for giving me release for this study, the Director of the animal production research center – Kuku and the staff of livestock fattening research department for providing me the animals and feed stuff and laboratories and making all facilities available.
Abstract

The study was conducted to examine the effect of target slaughter weight on feedlot performance, carcass and meat quality and the economic of meat production. Forty-eight western Baggara bulls were divided into four groups of similar body weight (164.55±3.9 kg) and all groups were intensively fed molasses based diet. The groups were randomly assigned to four target slaughter weights 200, 250, 300 and 350kg. A set of 8 external body measurements was recorded on each animal. Data on feed intake and live weight growth were collected on daily and weekly basis respectively. Bulls were sacrificed after they attained their predetermined slaughter weights.

Slaughter and carcass data were collected. The quality attributes of the meat from the four groups were also carried out. Analysis of variances was used to study the effect of target weight on feedlot parameters, carcass composition and meat quality. The value of the different external body measurements in predicting live weight was carried out using correlation and regression analysis. The allometric equation in the logarithm form was used to describe relative growth of body components.

The bulls on the 200, 250, 300 and 350 target slaughter weight groups took 36.1, 91.58, 152.52 and 220.5 days to reach the target weight, respectively. The results indicated that the daily gain declined significantly (P<0.05) as the live weight increased. That was
accompanied by a significant deterioration (P<0.01) in feed conversion ratio. The daily dry mater feed intake proportion declined (P <0.001) as the body weight increased.

Economically the gross margin and the coefficient of private profitability declined as period on feed and live weight increased. The lighter bulls revealed the highest profitability while bulls slaughtered at 350 kg consumed higher level of inputs and profit turned in a negative value.

Heart girth showed the highest correlation coefficient (r =0.93) while body length scored the lowest (r = 0.65).

The proportions of noncarcass components from empty body weight declined significantly (P<0.001) as body weight increased with exception of omental and mesenteric fat, which increased with the increase of live weight. Omental and mesenteric fat grew at a higher rate than the whole body. Excluding the omental and mesenteric fat, all other noncarcass components grew at a lower rate than the empty body weight (b <1).

Carcass parameters such as rib eye muscle area, carcass length, leg circumference, abdominal and chest circumference, and subcutaneous fat thickness increased (P<0.001) with body weight increase. These parameters were also found to regress significantly (P<0.001) and positively with carcass weight. However, leg circumference had the highest correlation (R = 0.92) and abdominal depth the lowest (R = 0.66) correlation with the carcass weight. The dressing percentage increased (P<0.001) with the increase of slaughter weight till 300 kg live weight and thereafter the increase was not
Chilling shrinkage declined (P < 0.001) from 3.24% to 1.95% as slaughter weight increased from 200kg to 350kg.

The muscle, fat and bone absolute weight increased (P<0.001) with the increase in carcass weight however muscle grew at approximately the same rate as the whole carcass (b = 1.03), while bone developed at a lower rate (b = 0.64) and fat grew at a higher rate (b = 1.25) than the carcass. The proportion of muscles tissues in the carcass increased from 64.09% for the lighter group to reach 65.9 % for the heavier one. Bone percentage declined (P<0.01) from 19.44% to 15.69%, whereas fat percentage increased (P<0.01) from 16.10 % to 19.39 % as the carcass weight increased. The muscle: bone ratio increased (P<0.01) whereas muscle: fat ratio decreased (P<0.05).

With exception of shin all forequarter joints grew at a higher rate than the whole carcass i.e. growth coefficient (b >1), while wholesale cuts of hindquarter developed at a lower rate (b <1).

Water holding capacity improved (P<0.001) as live weight increased and consequently cooking losses decreased. The intensity of red colour increased (P<0.001) whereas increase in lightness and yellowness was insignificant (P> 0.05).

Proximate chemical analysis indicated that meat from lighter bull had higher moisture content which declined (P<0.01) in heavier weights. Muscle content of crude protein and ash remained unchanged, but fat content of Longissimus dorsi muscle increased significantly. There was a significant increase in sarcoplasmic protein (P< 0.01) and myofibriller protein (P<0.05) with increasing slaughter weight but
nonprotein nitrogen increase was only significant between meat of bulls slaughtered at 300 and 350kg.

The objective and subjective evaluation revealed that meat from lighter Baggara bulls was more tender (P<0.01) than meat from older bulls. Panelist favoured the colour of meat from lighter bulls over that of heavier bulls. However panelists rated meat from heavier bulls as more juicer than that of lighter bulls.
ملخص الأطروحة


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Chapter one
Introduction

There is a paucity of data concerning growth performance of Tropical zebu cattle as compared to the immense literature on this subject for temperate breeds. Somewhat more than one-third of world’s cattle population is to be found in the tropics and within the tropics. The largest concentrations of cattle are found in Northeast and east Africa (Williamson and Payne, 1978). Sudan as one of the North East Africain countries, with a total cattle population of 39.479 millions head (Appendix 1) (Livestock Economic Department, 2003), topping Arab World and ranking second in Africain Continent (Winrock International, 1992). Sudanese cattle population is classified into two main types: Northern Shorthorn Zebu and Nilotic cattle. The former includes Baggara cattle, which are raised by pastorlists (Baggara Arabs of the Western Sudan). These animals are in continuous traveling on hooves migrating down southward to the higher rainfall regions in the dry season, up to Bahr el Arab, while during wet season they retreat northward to escape the biting flies and the mud (Williamson and Payne, 1978). Their numbers are estimated as 12-14 million heads (LED, 2003).

On their natural habitat these cattle graze various ecological subdivisions of low woodland Savannah. Severe seasonal fluctuations in feed availability affect live weight and growth to a considerable degree and hence considerable weight losses would occur by the beginning of May and continue until July (Wilson and Clark, 1975).
This Nomadic range system constitutes the backbone of beef production in Sudan. The contribution of beef production to natural growth Domestic product GDP was increasing annually since 1981 and in year 1991/1992 the livestock contributed 11.6 and 30% in grand GDP and Agricultural growth domestic products GDP respectively. In 2002 livestock contributed 50% in agricultural GDP according to Bureau of statistics, National Income (BSNIS 2003).

The bulk of beef cattle is herded by nomads and depend exclusively for their subsistence on natural grazing. Fluctuations in feed supply and inadequate grazing as regard quantity and quality constitute a major problem in this system of beef production, because it depresses live weight growth and lower beef quality. In this system of cattle production it is a must that cattle should be finished before they could be sold.

There are several factors that affect performance beef cattle in the feedlot including, type of cattle, initial weight. Initial age, target weight, quality and quantity of finishing rations.

The objectives of this study are: -

1- To study the effect of target slaughter weight on the feedlot performance, body dimensions, profitability, carcass and meat quality of Sudan western Baggara male calves.

2- Prediction of slaughter weight from body measurements.

3- Study of relative growth of body and carcass components.
Chapter two
Literature review

2.1. Feedlot performance

2.1.1. Feed Intake

The voluntary feed intake of an animal varies with animal and diet characteristics where live weight, fatness, genotype and sex are the main factors affecting feed intake. Other factors include health, housing and environment (Beranger and Micol, 1980). The amount of feed the animal can consume, both poor and high quality, determines productivity. The factors regulating how much the animal will eat are largely determined by the animal and its capacity to metabolize nutrients and that depends on age, weight of animal, stage of growth and sex (Orskov, 1998).

The higher the genetical potential for growth, the higher the daily dry matter intake, due to the greater demand and / or increased tissue builds up (Fox 1987). Energy requirement for maintenance and production are related to metabolic body size and hence dry matter intake (Vansoest, 1982). Greek, (1972) found that dry matter intake increased with time on feed and live weight gain. Animal eats to satisfy energy, but poor quality roughages intake is usually limited by the
capacity of digestive tract and the bulk density of roughages, which lead to low energy consumption (Blaxer, 1967 and Metren, 1985).

It is obvious that profitable fattening enterprise depends mainly on rate of growth. The faster the beef animal grows the less feed it will consume to reach market weight (Barrett and Larken, 1974). Merchen et al., (1987) reported that a ration with low energy increases daily dry matter intake. Eltaiyb et al., (1990) found that average daily dry matter intake for Sudan Western Baggara bulls fed different levels of concentrated diet varied from 9.5 to 10.5 kg/day, while Mustafa et al., (1990) reported daily dry matter intake of 10.4 to 11.6 kg per day when Western Sudan Baggara bulls were fed milled sorghum stover. Average daily dry matter intake reported by Mohamed (1999) ranged from 5.67 to 7.17 kg/day for Western Sudan Baggara bulls fed high and low levels of energy diet. (Eltahir et al., 2000) compared Baggara bulls and 50% Friesian crosses and found that daily dry matter intake was 7.33 and 7.2 kg/day for the two breeds respectively.

Comparison between Baggara and Kenana cattle revealed daily feed intake on dry matter bases of 5.16 and 4.74 kg per day for the two types of cattle respectively. Guma (1996) and Mader et al., (1991) studied the effect of dry and high moistured corn fed for beef cattle finishing diet and reported that the daily feed intake was 8.6 kg for dry corn and 8.22 kg per day for moistured corn diet. Lowering roughage content of the diet for beef cattle from (10% to 2%) lowered feed intake of finishing steers from 7.8 to 6.8 kg per day without affecting overall performance, (Bartle and Preston, 1991)
2.1.2. Animal growth:

Growth is a normal process of increase in size and weight produced by accretion of tissues similar in constitution to those of original tissues or organ; while development is the gradual progression from a lower to a higher stage of complexity as well as gradual expansion in size to acquire completely individual characteristics (Judge et al., 1989). Many researchers defined growth as an increase in weight of an animal in specified period of time. Brody (1945) and Pomeroy (1955) described growth as an increase in body height, length, girth and weight that would occur when a healthy young animal is given adequate food, water and shelter. Because growth is typically measured as increase in mass it includes not only cell multiplication (Hyperplasia), but also cell enlargement (Hypertrophy). Growth includes deposition of fat even though muscle mass is of primary interest in meat production. Mature size generally considered as the point at which muscle mass reaches its maximum (Owen’s et al., 1993).

Improvement in beef cattle production requires animals, which produce the best carcass at a minimum expenditure of time and maximum production of lean (Berg and Butterfield, 1966). Improving growth efficiency of food animals depends on understanding the relationship between size, growth rate and body composition (Black, 1988). Because leaner cattle tend to grow faster and use feed more efficiently, beef producers must pay attention for cattle frame size, growth rate and body composition, (Field, 1971).

2.1.2.1. Prenatal Growth

During embryonic development all tissues grow by hyperplasia, but as mammals mature specialized cells such as nerves, skeletal muscles
lose their ability to replicate and grow only by hypertrophy. Other tissues i.e. blood cells precursors, hair follicle, gastro intestinal epithelia, digestive tract organs and ectoderm continue to divide throughout the animal life (Owens et al., 1993). Most mammals are born with nearly their full complement of skeletal muscles fibers because muscle hyperplasia occurs primarily prenatally (Allen et al., 1979).

Growth begins with the fertilized ovum or zygote and proceeds through several distinct phases' prenatal (conception to birth) the faetal phase is characterized by different growth rate in various organs. Organs that have functional importance during foetal growth grow at early stages while others as digestive tract grow at late stages (Judge et al., 1989).

Early foetal growth is largely genetically regulated although blood flow later in pregnancy will alter foetal weight. Growth rate at later foetal stages and after birth but before maturity can be influenced greatly by factors such as plane of nutrition and environment (Gluckman, 1986).

Lean muscle fiber is early growing tissue and muscle fibers increase only slightly postnatal (Allen et al., 1979, Bergen and Merkel, 1991). During the foetal period and from birth to about puberty the rate of growth accelerates and after puberty it decelerates and reaches very low value as mature weight approaches (McDonald et al., 1981).

2.1.2.2. Compensatory growth

Animal whose growth has been retarded exhibits when feed restriction is removed a rate of growth greater than that, which is normal in an animal of the same chronological age. That fact was first noted by Osborne and Mendil (1915). This tendency of an animal to recover it’s body weight, by having higher than normal rate of growth when given
liberal amount of feed after a period of restriction has been termed compensatory growth and it is of greater importance and significance to agriculturist both in connection with growth and development of farm animals and the effect of period of subnormal nutrition on their carcass composition (Bohman, 1955). Barrett and Larkins (1974) reported that compensatory growth is the most important characteristics of growing cattle. When young cattle are ideally fed throughout their life; they grow rapidly until they reach their genetic maximum. In practice, however, there will be inevitable checks at weaning or because of draught in savannah. The severity of such checks depending on the nutritive state of pasture, these effects reduce weight gain with or without weight loss and that with the flush of new grass subsequent growth will resume at a rate more rapid than before.

From North Guinea, Zemmelink (1974) showed that unsupplemented cattle grazing uplands shrubs in dry season lost 300-400 grams body weight per head daily, however animals were able to grow rapidly and recover body weight during the following rainy season when abundant supply of good quality roughages were available.

In dry season in East Africa animals were fed poor quality natural pasture, low in nitrogen and energy content. Consequently animal raised on these feeds exhibit low growth, low mature weight, poor life time reproductive performance and low milk yield (Munjuni et al., 1990). Stephen (2001) practicing feed restriction on weaned calves on hay reported 15 pounds loss of weight when calves were returned to full concentrated diet but they gained 46 lb after 4 weeks. He concluded that
calves needed a period of adaptation before they began to gain weight following feed restriction.

The relative growth of body tissues under high plane of nutrition acts as reserved for animal nourishment under semi starvation period, the depletion of fats is the most rapid and the degree of the involvement of muscles and bones depend on the severity and length of period on semi starvation (Yeats, 1964 and Butterfield, 1956). Periods of low plane of nutrition do not seem to affect carcass composition when animals are allowed an adequate compensatory period on unrestricted diet recovery (Lawrance and Pearce, 1964)

2.1.3. Factors affecting growth

2.1.3.1. Plane of nutrition

Ruminants need daily supply of all nutrients required for maintenance, milk production and growth. Quantitatively any of these can be a limiting factor to performance, but the critical shortage is that of energy supply. Energy is needed to drive all metabolic and productive process and has the major effect of all nutrients, on production (Wilson and Brigstock, 1983). Animals on different planes of nutrition, even if they are of the same breed and weight will differ greatly in form and composition and when an animal is kept on sub maintenance diet the different tissues and body regions are utilized for supply of energy and protein in the reverse order of their maturity (Hammond, 1932, McMeekan, 1941, Pomeroy, 1955 and Wallace, 1948). High plane of nutrition accelerates live weight growth (Brookes and Vincelt, 1950). However, nutritional effect on growth is limited by the genetic make up of the individual animal (Pomeroy, 1955).
The rate of live weight gain is highly affected by level of dietary energy and protein and variations in energy level intake affect rate of growth in cattle (Smith et al., 1976). Anderson and Sexhus (1996) claimed that increased energy density in the diet resulted in an increase rate of gain. Levy et al., (1976) suggested that high and steady energy level from diet containing high plane of nutrition would produce the best results in term of gain rate and feed efficiency of intact male cattle. Live weight gain and overall daily gain of cattle was greater with high and medium energy ration than with low energy ration (Prior et al., 1977). Uro et al., (1987) studied the effect of different level of energy intake by Western Sudan Baggara cattle and found that, the rate of live weight gain increased in the group fed ad libitum than in the other group fed 65% on the ad libitum intake. The magnitude of the increase of the former group after 18 weeks was almost equal to the increase in the latter group after 32 weeks. Steen (1995) found that energy intake is the most important factor affecting the growth rate of beef cattle, he added that ad libitum fed animals had higher growth rate than those of 80% ad libitum.

On the other hand Broadbent et al., (1976) reported that a diet lower in energy concentration using cheaper feed sources will cause substantial performance depression for younger and lighter growing cattle. Blaxer (1967) indicated that when energy requirements for maintenance and growth were met, protein synthesis increased at a diminishing rate with increased energy, where fat deposition increased at increasing rate. Martin et al., (1963) found that calves fed high energy level had almost the same proportion of lean (by chemical analysis) and greater proportion of ether extract (7.2 versus 4.6%) in their carcasses.
compared with those fed low energy ration. While studying influence of energy level in calf nutrition Gruether et al., (1965) found that Herford steer calves fed high level of energy produces more total muscle than did those fed moderate levels at a constant age, but when the animal were compared on weight constant basis no significant differences were noted in lean content. The high levels of energy fed calves produced more fats than the moderate level calves on both age and weight basis. Crouse et al., (1984) found that heifer finished on forage had darker lean than those finished on concentrates. Bennett et al., (1995) found that lean colour was significantly darker (P<0.01) in forage finished beef than concentrate finished steers. Also (Binder et al., 1986) found darker lean colour in forage finished steers and attributed part of the darker colour to higher myoglobin concentration in longissimus dorsi muscle of forage finished steers.

Keane and Drennan (1980) studied the effect of diet type and feeding level on performance and carcass composition of Friesian steers serially slaughtered at different live weights. They reported that animal on high plane of nutrition produced about 10% more carcass gain than those on low plane and grew more efficiently and often accumulated more body fat than those given forage diet. Bennett et al., (1995) reported that the average daily gain during growing and finishing periods was significant (P< 0.001) for forage than concentrate finished steer. Mohammed (1999) reported lighter weight and lower average daily gain for bulls fed lower plane of energy than those fed higher plane of energy.

Dietary crude protein below 12.5% reduces daily gain for bulls (Martin et al., 1978). Optimum crude protein recommended for the
highest daily gain for Baggara cattle was 13.2% (Elshafie et al., 1976) and protein levels above 22.5% was associated with depression of growth rate and efficiency of feed conversion ratio (Cooke, et al., 1972).

2.1.3.2. Effect of breed

Although a great deal of beef cattle research has been carried out in U.S.A. and Europe a meaningful comparison between pure breeds are scarce, in spite that evaluating beef breeds, growth rate and feed efficiency must rank high in all circumstances in order to assist the intensive producer to select those cattle likely to perform best on his own particular feeding and management system (Preston and Willis, 1974).

Boyles and Riley (1991) while studying the performance of Brahman x Angus versus Angus steers reported that no differences existed in overall feed to gain ratio but Brahman x Angus crosses has more desirable yield grade and had longer carcass length which meant it had faster growth rate.

When post-weaning gain and feed efficiency of crossbred bulls, steers and heifer from Charolais Simmental and Limousine were studied by Newman et al., (1989), Limousine sired male calves gained an average 14 kg less than Charolais sired calves and 9.6 kg less than Simintal sired male calves. Differences in feed conversion ratio were generally small and non significant although Charolais sired bulls and steer calves were slightly more efficient than Limousine and Simmental sired calves. Limousine sired heifers calves tended to achieve the lowest rate of growth than those sired by Simintal or Herford. Beef cattle are grouped according to their growth rate into four groups by Mason (1971) Charolais, Simmental and Chianina were the prime group (Faster growing), Limousin and Maeine–Anjou were in the second group, Blode
d Aquitaine, Romagnola and Danish Red in group three while group four included the Angus, Herford and Shorthorn.

Selection of cattle for growth rate or for weight at a given age produces gradual increase in these traits (Frahm et al., 1985 and Sharma et al., 1985) and also tends to reduce fatness as reported by Preston (1968). The decrease in fatness probably related to the fact that selection for growth rate increase with mature size, because at a fixed weight, mature size and fatness are inversely related (Taylor and Fitzhugh, 1968). Bailey and Lawson (1989) studied breed effect on rate and efficiency of growth in Herford and Angus bulls selected for rapid growth and found that no effect of breed on rate or efficiency of gain between 50-500 kg live weight nor on the weight of digestive tract content but, selection for rapid gain on two different diets produced bulls that after 18 years of selection exhibited only minor effect on body composition and none on rate, efficiency and composition of gain. A comparison of growth rate of bulls of different breeds showed that at the same age, Charolais bull had the highest daily gain (1.9 kg/day) followed by South Devon, (1.08 kg/day), Herford (1.03 kg/day), Beef Shorthorn (0.97 kg/day), Angus (0.95 kg/day) and Gallway (0.92 kg/day) in that order (Robelin and Tulloh, 1992).

Anderson (1975) found that the daily live weight gain of Red Danish bulls were 1.4, 1.3 and 1.2 kg during growth periods from 200-250, 250-300, and 300-350 kg live weight, respectively. Robelin et al., (1978) studied variations of growth in continental beef breeds and reported daily live weight gain of 1.58, 1.19 and 1.18 kg for Charolais, Friesian, and Limousine respectively. Preston and Willis (1974) reported
that pure Charolais and its crosses were considered to give the highest growth rate among all temperate breeds, then Simmental comes next followed by Chianina and Danish (red and white). Aberdeen Angus and Shorthorns were inferior to the other beef breeds. The Angus has a growth rate capacity 24% lower than Charolais. Renald et al., (1992) indicated that specialized beef breeds such as Herford and Limousin are characterized by a higher growth rate than the Dual-purpose breed, such as Friesian, South Devons, Brown Swiss and Premontose, which have a medium growth rate.

Comparison of *Bos indicus* breeds have still to be investigated, the feedlot gain of Brahman fed cereal based diet was 3 to 13% lower than that of Angus and Charolais respectively (Peacock, 1982). Berg and Butterfield (1976) reported that indigenous breeds in Africa were slow maturing and have inferior conformation compared with temperate breeds. Joubert (1954) reported that the growth of Angoni (*Bos indicus*) breed was quite different from the growth of *Bos taurus* on both tropical and temperate conditions. (Walker, 1957a,b) suggested that the growth curve of African indigenous cattle showed considerable differences from Bostaurus. Williamson and Payne (1978) claimed that tropical Africa cattle had extensive genetic variability, which could be used as starting point for all sorts of progress in beef quality. White Tachner and Jahnoke (1992) reported that genetic limitation retards beef cattle potential in the tropics so only substantial increase yield can be achieved by improving animals living conditions.

Elshafie and McLeroy (1964) studied performance of Western Baggara bulls of different ages (18, 24 and 30 month) that were fattened
for 100 days with average initial weight of 132.4 kg and slaughter weight of 224 kg. They found average daily gain of 1.00, 1.11 and 1.19 kg for the three age groups respectively. Elshafie (1966) reported that there was no difference in daily weight gain (0.84 kg) for two groups of Western Baggara bulls, at the same age, fed on conventional and agro-industrial byproducts while, Mukhtar and Eltriefi (1970) reported a daily gain of 1.00 kg for Western Baggara bulls fed sorghum based diet. For 20-month-old Baggara bulls Mukhtar and Elshafie (1972) reported an average daily gain of 1.1kg during 90 days of fattening period on a conventional concentrate ration added to low quality roughage. Ahmed et al., (1977) reported 1.25 kg daily gain for Baggara bulls while Gaili and Osman (1977) reported average daily gain for Western Sudan Baggara bulls, kept on two different rations 1.31 and 1.23 kg. Gaili and Osman (1979) fed four groups of Western Baggara bulls at initial weight of 155, 179, 205 and 310 kg, on concentrated ration and reported that average daily gain was 1.13, 1.15, 1.24 and 1.36 for the four groups respectively.

Mustafa et al., (1990) reported an average daily gain for Sudanese Zebu cattle as 1.4 kg. Ahmed and Pollott (1977) studied the performance of yearling Kenana calves (Sudan Zebu) fed on 3 levels of dietary protein (117, 155, and 201 g/kg dry matter) and reported average daily gain of 0.55, 0.75 and 0.85 kg for the three protein level respectively. Elkhidir et al., (1988) kept Kenana bulls in two groups, the first group was offered 80% cotton seed meal and 20% sorghum straw while the other group was kept on concentrated diet composed of 60% sorghum grain 20% wheat bran, 19%cotton seed meal and 1% common salt in
addition 20% sorghum straw was offered. The average daily gains were 0.939 and 1.114 kg for the two diets respectively. Elshafie and Osman (1965) reported an average daily gain of 0.91 kg for Butana bulls.

Gumaa (1996) studied the difference in performance between Baggara and Kenana cattle on high-energy diet and reported an average daily gain of 0.90 and 0.84 kg for the two breeds respectively.

2.1.3.3. Effect of Sex
Wide variations in animal growth rate, feed efficiency and carcass composition of bulls, steers and heifers are cited in the literature. Micol and Branger (1984) reported that bulls grew faster and produce more lean meat compared to steers and heifers. Since calf sex is one of the most important factors affecting the variation in pre-weaning traits (Vesely and Robinson, 1971 and Singh, et al., 1970) bull calves are heavier at birth than heifers and grow more rapidly from birth to weaning. Castration of bull calf delay the maturity age and at all ages bulls made faster gain than steers (Arthaud et al., 1977). The growth rate of bulls, on average is 20 to 32% higher than that of steer and heifers respectively (Boucque et al., 1992). Knapp et al., (1940) reported that in beef shorthorn male calves were on average 2.1 kg heavier at birth than females.

Heifers deposit less muscles and more fat than do steers resulting in carcasses that, are less desirable both economically and nutritionally. Therefore a shift towards partitioning of nutrient towards muscle growth rather than fats should increase production efficiency (Miller et al, 1988). Repartioning agents such as Clenbuterol or Cimaterol increase muscle growth and decrease fat accretion when fed to steers or heifers (Ricks et al., 1984). Williams et al., (1965) studied differences due to
sex, between bulls, steers and heifers and reported that average daily gain was significantly higher in bulls (P<0.01) than steers and heifers. Heifers deposited less muscle and more fat than steers. Field, (1971) demonstrated that bulls gained more rapidly, converted feed to lean meat more efficiently and had less waste fat than steers, but meat from bulls generally had less marbeling, coarse texture, dark colour and was less tender than meat of steers.

Arthaud et al., (1977) Reported Warner-Bratzler shear force value was higher in bulls than steers in meat; and taste pannel evaluation showed that steer displayed more tender *longissimus dorsi* muscle than bulls. Juiciness favoured steers over bulls but the differences were small. Flavour and odour evaluation suggest that differences between bulls and steers were too small to be of practical importance.

Newman et al., (1989) studied post weaning gain and feed efficiency of crossbred bulls, steer and heifer and found that heifers tended to have lower rate of growth than steers and bulls. Johnson et al., (1984), Hunsely et al., (1971) reported that sex and age were of equal importance in affecting meat tenderness, while Field et al., (1966) did not detect any significant difference between bull, steers and heifers in the age range of 300 to 399 days. Beyond that range however differences started to widen in favour of steers and heifers. Most studies showed that intact male were superior to castrates and females in cutability, feed efficiency and lean to fat growth and that differences in tenderness were very small to hinder the production of meat from intact bulls (Turton, 1969 and Field, 1971). Reyneke (1976) reported average daily gain of 1.23, 1.01 and 0.1 kg for bulls, steers and heifers from 6 to 12 month old,
while Berg and Butterfield (1976) reported slightly lower range of live weight gain as 1.07, 0.984 and 0.869 kg/day for bulls, steer and heifers, respectively.

With the same diet, Neimann-Sorensen (1979) reported that the rate of gain of heifer was 18 to 30% lower than in bulls of the same breed. However, Jones et al., (1968) reported that the growth potentials of heifers increased with increasing mature size.

2.1.3.4. Effect of age

High quality beef is usually produced from specialized beef animal and bulls make the best beef and are preferred when they are slaughtered at younger age (12-24 months). Animals in this age produce cuts, which are small, tender and most desirable (Field, 1971). At a young age range between 300 and 399 days. Field et al., (1966) could not detect any difference between bulls and steers or heifer, beyond that range, however, difference started to widen. Carcasses from younger bulls had reasonable level of acceptability (Field, 1971). Elshafie and McLeroy (1964) studied the effect of age on the performance of Western Baggara bulls kept on agricultural by-product for 100 days. They found that the average daily gain (kg) was 1.0, 1.1 and 1.19 for bulls with an initial age of 18, 24 and 30 months respectively. Fawzi and A/Rahim (1967) studied the performance of Kenana bulls on feedlot at 9 and 20 months of age and reported an average daily gain of 0.9 and 0.6 kg respectively. Younger animals consume less feed and achieve more efficient gain than older animals. Mukhtar and Elshafie (1972) studied the performance of Western Baggara bulls from birth to 20 months of age and reported an average daily gain of 1.1 kg. Davis (1955) and
Morrison (1959) claimed that young animal required much less feed per kg of gain in weight than older ones.

Rate of growth and composition of tissue accretion may be controlled by chronological age, in addition to other factors as energy intake, hormonal status, relative turnover of tissues and cell activity (Owen et al., 1995). Actual weight records made within specific age interval must be pre adjusted to a fixed age and records outside this age intervals are of no importance because the accuracy of live weight evaluation between different ages may be lowered (Nobre et al., 2003).

2.1.3.5. Effect of Hormonal Implants:

Growth promoting implants are slow release devices that are placed under the skin of the ear. They have been used in the United States of America for more than a quarter of a century to improve rate of gain and feed efficiency in commercial beef cattle. Research has shown that proper use of implants returns at least 10 dollars for each one Dollar invested. Implants increase growth hormones secretion via pituitary gland and insulin at cellular level resulting in increased synthesis of muscle tissues and frequently reduce body fat deposition, ultimately increasing growth and improving feed efficiency (Davis, 2002).

To enhance growth by implantation, calves must have sufficient nutrition to support stimulated growth. In other words implants will not compensate for in adequate nutrition. Implant will not improve growth if gain is less than 1.3 pounds per day before implanting. In stocker calves the response for implant depends upon the quality of forage and supplement. In feedlot calves the response depends upon the adequacy of the finishing diet and in all cases the calves must be healthy and parasites must be controlled for optimum growth response (James et al., 1997).
Newman (1990) reported that growth promoting implants increased growth rate and feed conversion ratio of steer, but implantation of intact bull had given variable results. Gregory and Ford (1983) observed that growth promoting implants increased growth rate of bulls while Gordon et al., (1988) studied the effect of anabolic implants on reproductive function, performance and carcass characteristics and claimed that they did not affect intact bulls. Newman et al (1990) recorded that implantation of young bulls at 3 monthes of age reduced gain in hip height during feedlot period but it did not affect gain in body weight, body length nor the absolute level of triat. Lemieux et al., (1990) reported that implanting steers increased daily body protein gain during growing (P<0.12) and finishing (P<0.03) phases. The increased rate of protein growth during the growing phase occurred concomitantly with utilization of fat in slow growing animal and reduction of fat gain in others during finishing phase. The increase rate of protein synthesis rather than fat deposition reflected repartitioning of nutrient to protein growth rather than fat deposition.

β-Adrenogenic agonist L-644, 969 fed to beef cattle revealed that over all gain rate was not significantly changed by feeding (L-644, 969) at 0.25, 1.0 and 4 part per million. All improvement in growth rate and feed efficiency occurred during the first four weeks of treatment. Steers fed 1 part per million were more efficient than the control during the first 4 weeks of treatment; this increase in growth was followed by a gradual decline within the period of treatment. Treatment increased carcass weight and decreased weight of the hide and internal organs, thereby increasing dressing percentage (Moloney, et al., 1990).
2.1.4. Efficiency of feed utilization

Efficiency of feed is defined as the amount of feed required to produce one unit of live weight gain and it is of vital importance in the economic of fattening (Lister et al., 1976). Levy et al., (1968) claimed that feed efficiency decreased with the increase in live weight and duration of fattening. Improving growth efficiency of food animals depends on understanding the relationship between size, growth rate and body composition (Black, 1988). Leaner cattle tend to grow faster and utilize feed more efficiently (Field, 1970). Feed conversion efficiency was significantly inferior (5.8) in heavier animal 500-600 kg live weight than in lighter animals (5.45) (Romita et al., 1980). Thiessen et al., (1984) reported that as the animal body weight increased feed conversion efficiency decreased and they reported values of 5.52 and 13.4 for Dexter and British Charolais breeds fed on a concentrated diet.

Newman et al (1990) reported that castration reduced feed conversion efficiency by 13%. Lean intact male produced higher carcass yield, but generally lower quality grade. On the other hand steers tended to accumulate more external fats, which was accompanied by decreased weight gain and lower feed conversion ratio than do intact bulls (Schanbacher et al., 1983). Anderson et al., (1988) examined differences between intact males and steers in food conversion ratio and found that bulls were more efficient than steers and had a conversion ratio of 4.6 compared with 5.6 for steers. Preston and Willis (1974) compared feed conversion efficiency for bulls and steers on an all concentrate diet and found that the average food conversion ratios were 7.1 and 8.1 kg for bulls and steers respectively.
Cattle given a diet high in concentrate grew more efficiently and often accumulate more body fat than those given forage (Baily, 1989). Aston and Tayler (1980) fed maize and grass silage for young Friesian bulls and found that average food conversion values obtained were 7.5 and 7.7 kg dry matter per kg live weight gain for maize and grass silage respectively.

Newman et al., (1989) reported that breed sire differences in feed conversion ratio were generally small and non-significant although Charolais sired bull and steer calves were slightly more efficient than Limousin or Semmental sired calves.

*Bos indicus* breeds have almost lower feed efficiency than *Bos taurus*, while crossbred cattle were intermediate. The average respective values of feed conversion ratio of Boran, Herferd and Aberegeen Angus were 16.6, 8.1 and 8.4 kg dry matter per kg weight gain (Ledger et al., 1970). Jepsen and Greek (1976) reported conversion ratio of Arussi and Boran fed high level of molasses diet, as 12.7 and 11.9 DM for the two breeds respectively. Eltahir (1994) reported that 50% Friesian crosses were more efficient than Western Sudan Baggara bulls and he reported 5.58 kg DM for kg gain for Friesian crosses and 6.5 Kg DM per kg gain for Baggara bulls on molasses based diet. Elshafie and McLeroy (1964) studied the response of Baggara cattle to a fattening ration composed of agricultural by-products and reported feed conversion ratio of 6.5, 7.9 and 9.2 kg DM per unit live weight gain for age group ranging from 12 months to three years old. Ahmed et al., (1977) reported feed conversion efficiencies of 8.37 and 8.83 kg DM per kg live weight gain for two groups of Baggara bulls fed two different concentrate rations, while
Mustafa et al., (1990) reported 7.4 and 8.5 kg DM/kg live weight gain for two groups of Western Baggara bulls fed different level of milled sorghum stover in a conventional diet. Eltayib et al., (1990) offered rations with different levels of sorghum Stover (100, 75, 65 and 55%) to a concentrated mix and reported that feed conversion efficiency was 8.6, 10.8, 9.5 and 9.5 kg DM/kg live weight gain for the four groups respectively. Waddad and Gaili (1988) fed two groups of Western Baggara bulls either ad Libitum or restricted (65%) concentrated diet and they reported that the group fed ad Libitum achieved a live weight gain 1.4 times that of the restricted group, but the two groups have similar feed conversion efficiency. Elhag and George (1981) reported that the difference to efficiency of feed conversion was significant (P<0.05) between treatments groups of western Baggara bulls finished on agricultural by-product. Values ranged from 6.3 to 7.4 kg DM per unit live weight gain.

2.1.5. Growth measurement

2.1.5.1. Live weight

Live weight changes are comparatively easy to measure by determining live weight, carcass or body tissues weight (Brody, 1945). The daily variations in live weight due to feed and water consumption make live weight inaccurate measure for growth, as growth is routinely measured as change in live weight or mass. It follows holding feed or water and measuring fasted animal body weight is more précised index (Zinn, 1990). A more precision index of energy and nutrient consumption measure, is the empty body weight, where the digesta is completely removed from the gastrointestinal tract after the animal is slaughtered (Stock et al., 1983).
Many authors reported that initial live weight affected growth. Preston (1987) reported that heavier starting weight achieved higher intake in the feedlot and hence higher growth rate. Preston and Willis (1974) found that carcass weight increased with live weight in linear relationship. Since body weight increases with age, a positive relationship between age and dressing percentage is expected. Calf producers use live weight as the decider for placing cattle in feedlot. Analysis indicated that live weight is a more reliable predictor of feedlot performance than age. It was found that each 10 pounds, heavier a calf on initial weight weighed 3.7 pound more at the end of the period (Lashell et al., 2000).

Recently researches indicated both early growth rate estimate and mature weight are important in multiple triat selection programs for profit (McNeil and Newman, 1994). Most beef genetic evaluation programs provide predictions for only point estimate of birth weight. However, a more comprehensive description of individual animal growth can be estimated using, birth weight, weaning weight or mature weight and other measurement later in life (Kaps et al., 2000).

2.1.5.2. Growth measurement

Live weight gain is an important measurement used to assess growth of meat animals. Growth is defined by Pomeroy (1955) as gain of live weight per unit time and body measurement. Johnson (1984) found that the rate of gain under standard condition has been advocated as a main criterion of potential merit of meat animal for breeding purpose. It was also thought to be highly related to efficiency of gain and compatible with carcass merits.
Rate of gain is calculated as a change in weight during specific time interval. Even when weight is measured numerous times during a study period, weight changes from the initial to the final date typically is used to calculate growth rate, but regression across the various time points smoothes growth curve. In contrast calculating rate of gain from only two-fixed time points (initial and final) gives a sharp curve, (Tolley et al., 1988).

One method to circumvent the problems of selecting animals for larger mature size when selecting for growth rate, is to calculate growth rate on a relative (fractional) rather than on absolute basis. This might enhance metabolic efficiency at other stages of growth. Another index, growth rate as a fraction of mature weight might prove preferable to both absolute and relative growth rate during a period by mature body weight. This index should avoid the bias associated with leaner mass at a given weight of animals with greater mature body size and that be more précised as index of metabolizable efficiency (Owen’s et al., 1993).

Growth traits such as birth, weaning and yearling weights are recorded and routinely analyzed in genetic evaluation for beef cattle. In addition, some important traits, such as relative and absolute growth rates, maturing rates and mature size, can be derived by using growth function (Kaps et al, 2000). Function was first described by (Brody, 1945). Beltran, et al (1992) reported that Brody’s model gave adequate prediction of weight from 18 month to maturity, but early weights were slightly over estimated. Weight traits that change with time could usually be recorded as a mathematical model by non-linear function such as Brody’s growth curve, which has been used to describe beef cattle
growth. The parameters of the curve estimated for each animal should include the variances due to environmental effect and other variance component (Fitzhugh, 1976).

Mathematicial equation can be developed to characterized growth of an individual species, organs or tissues when discussing growth responses and maturity measurement. The equation must be clearly defined as the mathematicial formula used to calculate growth rate could alter interpretation of data e.g. absolute versus growth rate, (Tayler, 1980).

Growth curve summarizes information needed to understand the biological phenomenon of growth, which is an important component in beef production system. Development of growth model that describe growth pattern of a herd with in a particular environment and management system may be useful to determine the relative important factors affecting production efficiency (Olson, 1993). Allometric function (Y=bx^a) has been widely used, where Y is the weight of the tissue or compositional component and X represents the weight of the whole entity (i.e. empty body weight, live weight or carcass weight) (a) is constant while (b) stands for the regression coefficient. The relationship depends on (b) value the regression coefficient. When the values of (b <1), means that the organs or tissues grow at a lower rate than the whole body weight. When (b >1) that means the organ grows at a higher rate than the whole body. (Moughan et al, 1990 and Gu et al 1992). That equation resemble (Huxley’s, 1932) equation for growth and development. Allometric equations have several advantages including: 1) simple stable linear solutions after the log-to-log transformation. 2)
Straightforward biological interpretation and 3) simple stable derivatives (Wanger et al. 1999).

2.1.5.3. External body measurements

A paucity of knowledge seems to exist concerning the use of external body measurement for estimating and predicting the weight of various parts of beef cattle. Study of the relationship among weights and other measurement could be of practical importance in the evaluation and selection of animals (White and Green, 1952). Body measurements have been used for the prediction and estimation of body weight in beef cattle during fattening period (Lush, 1928) to predict growth rate and efficiency of gain (Kohle et al., 1951) carcass grade and dressing percentage (Cook et al., 1951). Linear measurements of height should not be interpreted as replacement for weight of an animal at specific age; instead height data should be used only as supplement for growth data. No specific size of an animal is the best for feed resources, breeding system and production cost. The market will determine the optimum size of an animal with given set of production resources (Brown et al., 1986). Many breeders provide measurement of large bones growth (frame score) as indicator for mature size; heights at hip or shoulder were generally reported as constant with age (Taylor, 1968).

Height of beef animal at a given age can be used as estimate of its maturity, type or growth curve potentials. It may assists breeders to determine whether or not an animal will fit into breeding program. Height can be used as an aid to predict growth and fattening pattern as well as its mature size. In this way frame size can be helpfully adjusted to other performance records when selecting stocks (McKiernan, 2000).
Newman et al., (1990) reported that castration reduced linear measurements where bulls exceeded steers in hip height by 10% and body length by 9%. Bulls had less depth over the 12th rib. Implantation of growth promoters reduced gain at hip height during feedlot period but it did not affect body length.

All width measurements of carcasses were found to be highly correlated with corresponding live animal measurements. These estimates were all higher (except for width of crops) than similar estimates made between subjective live animal scores and carcass measurements. Height at rump is highly related to carcass length accounting for 64% of the variation in weight, ribeye area and live weight. Correlation coefficient of 0.51, 0.52 and 0.53 were obtained between ribeye area and body circumference at fore-flank, hind flank and circumference at the middle, respectively (Orme et al., 1959). According to Lawrence and Fowler (1997) and El Khidir (1980), height measurements reflect the size of the skeletal units only, the soft tissue only or both soft tissue and skeletal units. Heart girth was described by Lawrence and Fowler (1997) and Sulieman et al. (1990) as the circumference of the chest and it is a measure of both the skeletal and soft tissue. They also noted that heart girth is the most variable measurement with live body weight since it reflects the body condition and in some cases the physiological status of the animal. Height at wither is considered as a measure of skeletal growth. The height of an animal had also been found to be a useful indicator of animal performance in feedlot; taller animals grow more quickly and laid down less fat than shorter animals (McKiernan, 1998). This was also reported by Agag
(1994) when he compared the taller Nylawi and the shorter Meseria subtypes Western Sudan Baggara cattle.

At constant live weight, circumference of body at fore-flank was associated with 81% of the variation in rib eye area, while circumference of middle rear flank, hind leg above hock and width of rump were also significantly related to ribeye area. Live animal weight and various animal measurements showed high relationship to wholesale cut yield (Orme et al., 1959).

Allometric relationship \((y = a.x^b)\) between live weight and various linear body dimensions showed considerable variations. The value of the exponent \((b)\) (the slope of the relationship on a long plot) in objects that maintain their shape as they grow that the weight is proportional to the 3\(^{\text{rd}}\) power of the linear dimension \((b = 3)\). Values of \(b\) greater than 3 were found exclusively for dimensions that relate to the extremities (head and limbs) and reflected that these organs were large proportion of their mature size at birth than was the trunk (Palsson, 1955). McNitt, (1983) reported an empirical formula for use with East African Shorthorn Zebu cattle that has been developed at Bunda College of Agriculture. This formula:

\[
W = 0.0004 \ G^{2.678} \quad \text{(Where, W is the body weight in (kg) and G is the heart girth in (cm)).}
\]

Baily and Lowson (1989) claimed that measurements of heart girth were less than 3. This result is probably due to the fact that these measurements reflected both bone growth and enlargement of the overing soft tissues.
2.2. Body components

Brody (1964) reported that as animals grow they do not simply increase in weight and size but, they also show what is termed development, which means the various parts of the body grow at different rates, so that its proportion changes as animal matures.

2.2.1. Non-carcass components

Non-carcass components are the organs that are not part of the commercial carcass and do not provide direct return to the animal producer, however they constitute a large proportion of the live animal. The developments of these components are mainly affected by age and nutrition (Wise et al., 1961). Animals on high plane of nutrition contain heavier visceral organs than those on low plane. With proceeding age noncarcass components such as head, feet and lungs increase in size and weight (Owen and Norman, 1977).

Jesse et al., (1976) found that as empty body weight increased from 196 to 509 kg, the percentages of noncarcass component decreased in the following pattern 11.2 to 9.39 and blood percentage decreased from 3.66 to 2.77.

The overall mean of hide, head kidney fat and caudal fats were reported for Danish cattle in term of percentage of live weight by Bech Anderson et al., (1977) as 7.9, 3.2, 1.05 and 0.81% respectively. Clottey (1973) studied the characteristics of Chalian Lyre-horned zebu and the percentages of head shank and hide to be 7.8, 3.2 and 9.4% respectively. Data from N, Dama cattle in Sierra Leone were collected by Boston et al., (1975) and the values were 5, 2.6 and 9.5% for head, shank and hide respectively for steers with mean carcass weight of 103 kg. Similarly
Raude et al., (1975) found that the percentage of head and hide of Nguni steers were 5.3 and 8.5% respectively in carcasses weights 202 kg. Butterworth and McNitt (1983) while recording carcass characteristics of Malawi Zebu breeds measured the percent on live weight basis for liver, hocks, head, tongue and hide and reported values of 1.2, 1.9, 3.9, 0.3 and 6.5% for these organs respectively. Data from Western Sudan Baggara bulls related to non-carcass components reported by Elshafie and McLeroy (1964) indicated that the percentage of organs, on slaughter weight basis, were 1.2, 0.7, 5.6, 7.8, 1.9, 0.4, 0.3 and 0.3% for the liver, lungs and trachea, head, hide, feet, heart, spleen and kidneys, respectively. Elshafie et al., (1976) reported values of 1.33, 1.07, 4.78, 8.33, 2.35, 0.38, 0.29, 0.13 and 0.26% for liver, lungs, head, hide, feet, heart, spleen, testicles and fat for Western Sudan Baggara cattle having an average slaughter weight of 229.8 kg. Eltahir (1994) reported that as a proportion of empty body weight, the live weight of hide, mesenteric fat, kidney fat and genital organs were heavier in Western Baggara cattle than in 50% Friesian bulls, but the percentages of the head, feet, intestines, omental fat, kidneys, liver, heart, lungs and trachea, spleen and tail were not different in the two breeds. Gumaa (1996) working with Western Sudan Baggara and Kenana cattle reported heavier omental fat and gutfill and lighter hide, feet, heart, lungs and trachea for Kenana cattle. Mohamed (1999) found that the head and hide were significantly (P<0.05) heavier in Western Sudan Baggara bulls fed low dietary energy diet, but the intestines, stomachs, liver, lungs, diaphragm and oesophagus were higher when Western Sudan Baggara bulls were fed diet having high dietary energy. Robelin and Geay (1984) observed that
in early life the digestive tract content early in life represented less than 5% of body weight but this percentage increased rapidly to reach approximately 20% of body weight in cattle weighing 200 to 250 kg body weight. Thereafter, gutfill declined to reach less than 12% when shrunk body weight of growing animal reaches 350 kg. William et al., (1992) suggested that the digestive tract reached its mature size weight before other carcass components. This will cause the fill to be inversely correlated with fat content of the carcass.

2.2.2. Dressing percentage

Economically the animal value is based on the dressing percentage, which is the relation between carcass weight and live weight of an animal. It may be calculated as percent of full body weight or empty body weight. Berg and Micol (1991) found significant differences in dressing percentage of hot and chilled carcasses, hot carcass weight was greater (P<0.05) than cold carcass due to chilling loss. When slaughtered animal were subjected to a fasting period before slaughtering gut fill was reduced and hence the dressing percentage increased which indicated the effect of rumen fill on dressing percentage (Stubo, 1964).

Preston and Willis (1974) found that carcass weight increased with live weight in a linear relationship. Dressing percentage also increases with age and this bears strong relationship to the maturity of an animal, where maturity is defined as optimum relationship between bone, muscle and fat. With increasing age and fattening of animal the dressing percentage increases till a point and then it tends to cease. Palson and Verges (1952) reported that high growth rate of carcass component over noncarcass component led to increased dressing percentage with
increasing age and weight. Other factors affecting dressing percentage were sex, breed and plane of nutrition.

Researchers usually discriminate against grass fed beef because of lower dressing percentage, higher cooler shrinkage and lower quality grade (Schroeder et al., 1980). Smith (1990) discourages forage finishing of beef due to the lower dressing percentage and decreased quality grade.

Dressing percentage of 53% was reported by Hall (1962) for Sudan Zebu cattle on high plane of nutrition and good husbandry. Bennett et al., (1995) found there as a significant difference between dressing percentage of steer fed concentrated diet and those fed forage diet.

Elkhidir et al., (1988) fed Kenana bull on molasses based diet and reported an average dressing percentage of 49%. Eltahir (1994) reported that hot dressing percentage of Baggara bulls fed on molasses based diet, was 51.97% whereas 50% Friesian crosses dressed 53.51%. Gumma (1996) found no significant difference in dressing percentage of Baggara and Kenana cattle in feedlot but, Baggara bulls dressed higher and produce more edible lean meat than Kenana bull and that was attributed to the heavier carcass and higher degree of fatness of Baggara cattle. Mohamed (1999) found that the dressing percentage of hot and cold carcass on both slaughter and empty body weight basis were significantly (P<0.05) greater for Western Sudan Baggara bulls fed higher dietary energy than those fed low energy diet. Gaili and Osman (1979) reported no significant difference in dressing percentage of Western Sudan Baggara bulls of different initial weight at the same slaughter weight. Dressing percentage values ranged from 52.8 to 54% on full body weight basis while Gaili and Nour (1980) reported a range
of dressing percentage from 55 to 66% on empty body weight basis for Kenana bulls to the corresponded live weight range from 100 to 400 kg body weight basis for Kenana bulls. Eltahir et al., (2000) reported mean hot carcass dressing percentages on empty body weight basis 56.91 and 58.3 % for Western Sudan Baggara cattle and half-crossed Friesian bulls fed on molasses based diet respectively. For cold carcass dressing percentage they reported 55.19 % and 56.81% for Baggara and half-crossed Friesian crosses respectively.

2.2.3. Carcass composition

Factors affecting carcass composition are genetical and environmental. Berg and Butterfield (1976) studied the effect of growth on carcass composition and concluded that bone was relatively slow growing muscle was more rapid and fat deposition was relatively slow at early age, but at a certain stages of development fat deposition exceeds muscle formation.

Consumers demand for leaner beef necessitates a reduction in fat. It is generally accepted that reducing plane of nutrition of beef cattle reduces fat content of the carcass (Andersen and Ingvartsen, 1984). Carcass fatness normally increases with the increase of weight at slaughter; early maturing breed are fatter than later maturing breeds at a given weight (Kean et al., 1991). Kean et al. (1990) noted that proportion of bones and muscles were higher for Friesian than for Herford, while proportion of fat was higher for Herford than for Friesian and Charolais. There were no significant differences between Friesian and Charolais in bone, muscle and fat proportion.
The evaluation of beef carcass for carcass lean content is conducted in most countries by use of subjective scoring system for fatness and conformation (Jones et al., 1987). Fat is deposited at greater rate later in life than lean tissue. The intramuscular fat is a late developing tissue. Usually the trend of fat development order is abdominal followed by intramuscular then subcutaneous and finally intramuscular (David et al., 2001). Carroll et al., (1963) indicated that high level of dietary energy and protein after feed restriction resulted in increased lean and bone but not fat. Berg and Butterfield (1966) reported that the quantitative requirement in steer carcass are best met when the proportion of muscle is at maximum, bones at minimum and fat are at an optimum level which is determined by local consumer preference. Callow (1962) advocated laborious total carcass dissection techniques as the best measure for lean bone and fat content. The back fat was used for estimation of retail yield and was highly correlated in the negative direction (r = -0.72). This was expected since external fat depth was a negative factor in the formula used to calculate retail yield (Hamilton, 1995).

2.2.3.1. Wholesale cuts
The first step in breaking the carcass is to separate it into primal cuts that can be handled more easily. The primal cuts correspond fairly closely to the units that retail butcher might order from a wholesalesaler or abattoir (Prior et al., 1977). The distribution of cuts components as lean and bone can be studied by cutting the carcass into joints and separation of its tissue content (Kempester, 1992).

Mukhoty and Berg (1971), Kempster et al., (1976) and McDonald (1981) found that regression coeffecient for joint weight showed low proportion change with increasing carcass weight, the limbs and loin
grow slower, while thorax, ribs and flank grew faster than overall side, thus the limbs and loin decreased as proportion and the remainder of the side increased as proportion of the side with the increasing weight. Owen et al (1995), found that empty body weight can be estimated from carcass weight, the relationship was linear with sizable deference in the intercepts (30 to 61) and the slope (1.36 to 1.45 times carcass weight). Holzer and Levy (1989) adopted an equation for estimating empty body weight, $\text{EBW} = (1.39 \times \text{carcass weight} + 60.6)$. Fox et al., (1976) developed the equation, $\text{EBW} = 1.4 \times \text{carcass weight} + 40.2$.

Kock et al., (1981) reported that wholesale cuts differed in economic value because of difference in composition and preference for lean content, hence the loin and ribs commanded the highest prices per unit weight followed by round and chuck in that order. Kempester et al., (1976) claimed that the higher priced joints accounted for 49% of total lean weight; half of this was in three large joints of the hind limbs (Silverside, Topside and Thick flank). The clod and neck accounted for most of the lean in the lower priced joints. The percent for ribs accounted for 4.6% of the side weight, wing rib 2.4, sirloin 6.3, rump 7.3, fillet 2.6, thick flank 6.6, topside 9.0, silver side 10.1, shin 2.3, clod and sticking 11.0, pony 20.7, coast 9.6, thin flank 3.5 and leg 3.9%. Adam’s et al., (1977) found that percentage of forequarter and hindquarter did not differ (P<0.05) among breed. The percentage of hindquarter were 47.5, 47.4, 47.9, 47.8, 48.5, 48.3, 48.3 and 48.1 for Herford, Angus, Lincoln Red, Brown Swiss, Simmental, Limousin, Maine-Anjou and Charolais breeds in that order. For forequarter percentages the corresponding values were 52.5, 52.6, 52.1, 52.2, 51.5, 51.7, 51.7 and
51.9%. Keane et al., (1990) found that thoracic limbs were greater for Friesian and Charolais than for Herford (P<0.01), whereas, ribs and flank proportion were greater for Herford than for Friesian and Charolais. Thorpe and Cruickshank (1980) also studied carcass composition of Africandar, Angoni, Barostse and Boran breeds and found that average percent for forequarter were 47.4, 47.9, 47.3 and 47.6% respectively. Zebu breeds have similar wholesale cuts percentages. They only differed in percent of chuck and plate. The highest percent in Zebu cattle was for round and chuck but they have lower percent of kidney fat when compared to British Breeds (Cole, et al 1964).

The hump may account for greater variability in chuck percent, fatter breeds have higher percent of the minor wholesale cuts along the betty (brisket, plate and flank) that in turn decreases the percent of the major wholesale cuts down the back. Breed with long carcasses tend to yield higher percent of major wholesale cuts and separatable muscles (Cole, et al 1963). Elshafie and Osman (1971) studied wholesale cut yielded by Western Sudan Baggara cattle and reported that the percentage of chuck joint was 24.1, brisket and plate 10.8%, loin 14.7%, rib 7.7% and hind shank 3.2% of the side weight. Eltahir (1994) compared Baggara bulls and half-crossed Friesian crosses and found that the percentages of shin, neck, clod, chuck, extended roasted ribs, thick ribs, thin ribs, brisket, thin flank, thick flank, leg, sirloin, rump and topside and silverside percent were 2.95, 5.35, 5.52, 13.68, 9.53, 4.52, 1.87, 8.64, 5.0, 4.39, 4.47, 9.62, 6.8 and 17.59 of the carcass weight of Western Sudan Baggara bulls. Gumma (1996) found that the percentage
of whole sale joint for the same breed on carcass weight basis were 7.2, 5.5, 11.6, 8.9 and 16.5 for clod, thick ribs, chuck, extended roasting ribs and topside and silver respectively. Agag (1994) reported the following data for wholesale cuts as round, loin, ribs, chuck, flank, plate, brisket and fore shank 36.1kg, 26.2kg, 13.9, 42.6, 2.9, 9.8, 8.3 and 8kg for Nyalawi type compared to 33, 24.9, 12.6, 37.2, 2.7, 8.8, 9.1 and 7.2kg for Messiera type. There was no significant difference in round weight for the two subtype (23.8 vs. 23.70). There was a significantly (P<0.01) difference for loin and ribs. Chuck was significant (P<0.05) higher for the Nylawi type. Khogali (1999) reported that commercial cuts were greater in carcasses from Western Sudan Baggara bulls on high dietary energy level as compared with those from bulls on low dietary energy level with exception of extending roasting ribs.

2.2.3.2. Muscle: bone and muscle: fat ratio
Consumers demand is primarily for lean beef and the identification of carcass with superior lean is perquisite to provide target for cattle breeding (Jones et al., 1989). Berg and Butterfield (1966 and 1968) claimed that muscle: bone ratio is determined by carcass weight rather than fatness and they suggested that muscle: bone ratio might be taken as a criterion for carcass composition between cattle breeds. Waldman et al., (1971) reported that, muscle: bone ratio in Holstein Steers increased with animal weight and recorded muscle: bone ratios of 2.37, 2.74, 3.02, 3.42, 3.58 and 3.73 for steers slaughtered at birth, 91, 227, 341, 455 and 590 days of age.

Factors that affect muscle: bone ratios include the genetic potential of an animal (Brannang, 1966a), plane of nutrition and environment, (Preston and Willis, 1974). Gaili (1978) compared muscle:
bone ratio of Western Sudan Baggara bulls with international beef breeds and reported that at the same carcass weight muscle bone: ratio of Western Sudan Baggara bulls (4.04) was comparable to muscle: bone ratio of Herford (4.5 vs 4.35), Friesian (4.7 vs 4.8) and their crosses (4.36 vs 4.23) steers. Eltahir (1994) reported muscle: bone ratio for Baggara bulls and half-crossed Friesian bulls as 3.03 and 3.28 for the two breeds respectively. Gumma (1996) reported muscle: bone ratio and Muscle: Fat ratio for Baggara and Kenana bulls as 4.4 and 4.21 respectively. Khogali (1999) studied the effect of different energy level on Baggara bulls and reported that muscle: bone ratio was significantly higher in carcasses of bulls offered high energy level. Elshafie and McLeroy (1965) found that the meat: fat ratio was approximately 4.12 for Western Baggara cattle slaughtered at 301 kg. Elshafie (1968) reported meat: bone ratio that amounted to 3.0 at 9, 10 and 11th ribs of Sudan Zebu cattle slaughtered at 300 kg. Elshafie and Osman (1971) reported that muscle: bone ratio of 2.9 for Western Sudan Baggara bulls slaughtered at an average weight of 165 kg.

2.2.3.3. Carcass measurements

2.2.3.3.1. Longissimus dorsi muscle area

The cross sectional area of longissimus dorsi muscle has been frequently used as a measure of carcass lean. Henderson et al., (1966) reported that longissimus dorsi muscle area should be measured accurately and rapidly if large number of carcasses were to be evaluated because many variations could be detected in an equation to predict carcass lean by using that technique.

Carpenter and Palmer (1961) reported significant differences in longissimus dorsi area from the right and left sides of the carcass, while
Hedrick et al., (1965) reported that these differences were due to error in cutting carcasses. Henderson et al., (1966) used different techniques for measuring longissimus dorsi area and reported that cutting error contributed most to the inconsistency in determining of cross-sectional area. The different techniques differed significantly in the area values obtained but these differences were small compared with differences in longissimus dorsi between the right and left side; the values obtained ranged from 75.59 to 77.98 cm².

Field and Schoonover (1967) slaughtered bulls at live weights that ranged from 91 to 589 kg and reported linear increase in eye-muscle area throughout the entire weight range. Longissimus dorsi muscle area ranged between 33.11 to 90.29 cm². Jacobs et al., (1977) compared Hereford bulls and steers from the same herd and nutritional trait for eye muscle area and found that bulls had greater ribeye areas (83.9 cm²) than steers (73.5 cm²). Thorpe and Gruickshank (1980) reported that rib eye area of African breeds showed no significant differences between breeds and the, values obtained were 64.9, 64.4, 62.0 and 62.4 cm², corresponding to Africander, Barotse, Angus and Boran X Angou breeds. Meaker and Liebenberg (1982) reported that bulls had larger eye muscle area (P<0.05) than steers castrated either at 24 hours of birth, three months of age or at 6 months. Eye muscle areas were 58.9, 54.7, 54.7 and 52.9 cm² for bulls, steers castrated at 24 hours of birth, 3 month of age and 6 months of age respectively.

Mayer et al., (1965) and Mohamed (1999) reported that bulls given higher dietary energy had greater longissimus dorsi area than those offered low plane of energy. Abdelgalil (1997) reported longissimus
dorsi area of 54.4 cm² and 45.9 cm² for Western Sudan Baggara bulls, kept on two different sources of protein in their concentrated diets that were blood meal versus groundnut cakes.

Eltahir (1994) reported average longissimus dorsi area of 55.17 cm² and 56.33 cm² for Baggara and half-crosses Friesian bulls respectively. Gumma (1996) reported a corresponding longissimus dorsi area of 66.9 cm and 60.6 cm² for Baggara and Kenana bulls fed intensively on concentrate sorghum based diet. Turki (2002) reported longissimus dorsi area of Baggara cattle kept on four levels of protein sources that ranged from 44.1 cm² to 51.25 cm².

2.2.3.3.2. Back fat thickness

Back fat thickness over the longissimus dorsi muscle has been shown to be highly and positively correlated and a useful predictor of total percentage of fat and an indirect predictor of carcass lean (Brungardt and Bray 1963). Chadwick and Kempester (1983) compared visual fat score to both ruler and probe measurements of fat thickness in their ability to predict carcass lean content. Their results indicated that visual fat score was a more precise predictor of carcass lean than fat thickness measurement made by a ruler or a probe. Fat thickness measurement was generally found to be a more précise prediction of composition of cold rather than warm carcasses.

Back fat thickness and estimated retail yield were highly correlated in the negative direction (r = 0.72). This is expected since external fat depth is a negative factor in the formula used to calculate retail yield of large frame steers (Hamilton 1995). Quijandria and
Robinson (1970) suggested that back fat deposition is linearly associated with either age or weight. Keane and More O’ferrel (1992) reported that high concentrate level was associated with significantly reduced bone and increased subcutaneous fat proportions for Friesian steers. Carcass from bulls on low level of protein supplementation had less fat thickness and higher cutability than those on higher level of supplementation. Powel and Huffman (1973) reported that fat thickness is highly associated with carcass chemical composition.

McEwen and Mandel (1997) studied the effect of implants with (Ralgo, Revalor or Synovex-S) on carcass composition and meat quality in Charolais and reported that implants increased deposition of subcutaneous fat and the values were 7.7 mm for implanted steer versus 6.4 for the control. Bowling et al., (1977) studied carcass characteristics of forage finished beef animal and concluded that grain finished beef had significantly (P<0.05) thicker back fat (8.4 mm) than forage finished carcasses (4.1 mm). That finding was also confirmed by Mohamed (1999) who fed Western Sudan Baggar cattle different levels of dietary energy and found higher back fat thickness for high levels of dietary energy (4.5mm) and 2.3 mm for the low energy level. Denham (1977) found no significant breed differences in back fat thickness for animal kept on grazing without supplementation or when supplemented with cereal grains,. The records of overall average back fat thickness values were 1.22 and 1.32 cm on the two regimes for Herford, Angus x Herford and Charolais x Herford. Agag (1994) reported values for back fat thickness for Nyalawi and Messaria type of Baggar cattle, measured at the 12th ribs to be 2.0 mm and 3.1mm for the two types of cattle
respectively. Gumma (1996) reported high correlation coefficient of total carcass muscle with back fat thickness for both Kenana and Baggara bulls.

2.3. Meat Quality attributes

2.3.1. Tenderness

Consumer considers tenderness as the single most important component of meat quality; this fact is easily confirmed by the positive relation between price of cuts and its relative tenderness (Morgan, 1992). Inconsistency in meat tenderness has been identified as one of the major problems facing the beef industry (Morgan et al., 1991). Prediction of carcasses that produce tender meat and avoiding those yield tough meat brings the inconsistency because recognition of tender meat occurs when the meat is already eaten by the consumer and at that time it is too late for prediction (Boleman, et al., 1995). Thus there are economics incentives for predicting meat tenderness, because consumer considers tenderness to be the major determinant of eating quality. The factors that affect beef tenderness are sex, gender, age, implants protocol, preslaughter handling procedure, slaughter dressing, electrical stimulation, chilling, post-mortem tenderization technology and meat ageing (Koohmaraei, et al., 1996). Tenderness of beef at time of consumption is a complex characteristic that is determined by a range of intrinsic determinants within the muscle, many of which can be influenced, not only by the genetic and age of the animal, but also by many external factors. These may act during animal growth, during the preslaughterer period, during the postmortem period both before and after rigor mortis, and during cooking (Harper, 1999; Ferguson et al, 2001)
several factors affect myofibrillar tenderness of meat, but the relationship among these factors remains unclear. Sarcomeres length and post-mortum proteolysis have both been implicated in determining the myofibrillar tenderness of meat (Wheeler and Koohmaraie, 1994). Uniformity, excessive fatness and inadequate tenderness-palatability were all parts of the top ten-quality concern of beef industry (Smith, 1990).

Moloney, (1999) reported that there are two main components of meat tenderness; Myofibrillar (muscle) component and connective tissue component (collagens). The tenderness decreases with age however good animal handling prior to slaughter, appropriate chilling and aging post-slaughter can minimize muscle fiber toughness.

Therkildsen et al., (2002) studied the relationship between the growth and the myofibril fragmentation index (MFI) and the effect on tenderness and shear force on Longissimus lumborum and Supraspinatus muscles. They reported that sensory pannel revealed that (MFI) and tenderness were significantly (P<0.01) higher and shear force was significantly lower (P<0.01) in meat from high rate of growth compared with meat in medium rate of growth and the myofibrillar fragmentation index correlated positively with meat tenderness. Toughness or tenderness of meat depends on degree of post-mortum shortening and aging of myofibrillar protein, and the amount of mature connective tissues (Lawrie, 1991). Meat from younger cattle was significantly more tender than from older cattle and other factors affecting meat tenderness were chronological age, inheritance, biochemical changes during ageing period, chemical constituent of muscle, anti-mortum treatment and
deposition of fat in carcass and livestock management (Webb et al., 1964). Morgan et al., (1991) studied tenderness among meat cuts and found that top sirloin steaks were tougher (P<0.05) and received the lower sensory rating compared with the other loin cuts. In all cases roasts tend to be tenderer than steaks from sub primal source.

The round represented approximately 22% of the weight of typical beef carcass and contains some of the largest muscles. However, some of these muscles are the least tender muscles of the carcass. (Jones et al., 2000). Because of the large size of muscles of the round, tenderness evaluation of single steak may not necessarily represent the tenderness of the entire muscle. Furthermore if intramuscular tenderness variation is well-defined, alternative fabrication and merchandization methods could be developed to increase total carcass value (Reuter et al., 2002).

Breed effect on tenderness is clearly shown in beef from Angus carcasses, which is significantly (P < 0.05) tender than that of Hereford carcasses. The reported shear force values were 3.10 and 3.14 kg/cm² and the taste pannel scores of tenderness were 7.47 and 7.32 for the two breeds, respectively. The two breeds were significantly tender, (P<0.05) than Hereford crosses with Limousin, Charolais or Simmental, the corresponding shear force values for the three breeds were 3.41, 3.26, 3.51 kg/ cm² and the pannel taste records were 6.85, 7.18 and 6.62 respectively (Koch et al., 1976).

Slight differences in taste panel scores were detected in tenderness between bulls and steers (6.1 versus 6.6), however, the difference was not significant. Shear force measures indicated that bulls were slightly less tender (P<0.05) than steers. The range of shear force in bulls was
very high (6 to 14 kg/ cm²) as compared to steers (6-10 kg/ cm²). The overall mean of Warner-Bratzler shear force was 6.57 and 6.34 / cm² for bulls and steers respectively (Jacob et al., 1977). Crouse et al., (1987) have observed that meat obtained from Boss indicus breed crosses of cattle was less tender than meat obtained from Boss taurus cattle. Luckett et al., (1975) reported that Brahman crosses ranks less tender than British breeds on basis of shear force or sensory pannel observations.

Agag, (1994) in his assessment of meat quality in Nyalawi and Meseria bulls reported that taste pannel values were 7.8 and 6.3 for the two sub-types, respectively. Eltahir, (1994) while comparing local Sudanese Zebu breed and Friesian crosses reported values (4.05 vs. 3.04 kg / cm²) for shear force and 3.28 vs. 3.47 for taste panel for the two breeds, respectively. Guma, (1996) compared Kenana and Baggara bulls and reported shear force value of 4.25 kg/cm² for Kenana and 3.71 kg/cm² for Baggara cattle. Panelists value were 3.2 vs. 2.25 for the two breeds, respectively. Mohamed, (1999) indicated that shear force and connective tissues strength were significantly (P<0.05) lower in Western Sudan Baggara bulls fed high dietary energy level compared with the bulls on low energy level and that was attributed to carcass fat level which is known to dilute connective tissue content (Lawrie, 1991).

2.3.2. Colour

The first impression that consumers have of any meat product is its colour and thus colour is of atmost importance as it affects consumers purchase decission of red meat. The livestock industry is continually challenged to meet consumers demand for meat and meat products that
are palatable, yet maintain the bright cherry red colour indicative for freshness (Boles and Pegg, 2002). Colour of meat is influenced by the age of an animal, species, sex, diet and exercise. Meat from older animals gets darker in colour because the myoglobin level increases with age (FSIS, 2000). Because muscles differ greatly in activity their oxygen demand varies, consequently different myoglobin concentrations are found in various muscles of the animal. As myoglobin content increases meat becomes redder and darker (Valin et al., 1992). This appears in chicken legs, which is darker than its breast (Elizabeth 1993). Generally exercised muscles are always darker in colour, which means, the same animal can have variation of colour in its muscles (FSIS, 2000). The colour of meat is related to the level of pigmentation (myoglobin) present in muscle and the chemical status of this pigmentation (Lawrie, 1975). When beef is cut, the myoglobin oxygenates giving rise to bright red colour and prolonged period of exposure to oxygen turns the oxymyglobin to brown colour (metmyoglobin). High level of preslaughter stress can lead to rise in pH and lead to dark colour beef (Moloney, 1999). Also pigment differs among species. Beef has considerably more myoglobin than pork or lamb (Bole and Begg, 2002).

Pearson (1960b) reported that the four factors contributing to attractiveness of meat were colour of lean, colour of fats, trimness and cut texture. The most desirable colour varied between different individuals. Preston and Willis (1974) stated that the greater intramuscular fat content of grain fed animal the greater is the light reflection from muscles, which will make meat appears light.

Mohamed (1999) studied the effect of different energy levels on
Western Sudan Baggara bulls and reported that meat of bulls fed low energy diet had significantly ($P<0.05$) low lightness and high yellowness values than those offered higher dietary energy.

The colour can never be regarded as an independent quality variable because colour precipitation is correlated with other variable as Juiciness, pH and marbeling. (Preston and Willis, 1974). Beef with yellow fats is not desirable. The major cause of yellow colour is the intake of yellow carotinoid pigments; especially B carotine, which can be metabolized to Vitamine A. Excess B-carotine, is storded in fats giving yellow coloured fats (Moloney, 1999).

Eltahir (1994) reported significant breed ($P<0.01$) difference between Baggara and Friesian crosses. The latter produced more red coloured meat. He attributed these differences to maturity where Friesian is known to be a late maturing breed. Gumma (1996) reported that colour of Baggara bull meat had more lightness (L) 35.3 and less redness (11.9) value than Kenana cattle and that was attributed to the degree of finish as Baggara cattle had more carcass fat than Kenana.

2.3.3. Juiciness

Juiciness is an important component of meat texture and palatability and it has two major components; the first is the impression of wetness produced by release of fluids from the meat during the few chews. The second is the more sustained juiciness that appearantly results from the stimulating effect of fat on the production of saliva and coating of fat that build up on the tongue (Lawrie 1991 and Moloney, 1999).
Mandell et al., (1998) revealed no significant difference in the initial overall juiciness of longissimus dorsi muscle between steers finished on forage and those finished on grain. Breed effect on juiciness was reported for Charolais and Limousine where the latter was found to have more juiciness scores than the former (Mandell et al., 1999). Comparison for differences in juiciness between the Herford, Charolais Limousine and Simmental revealed no breed differences (McAllester et al., 1976). Eltahir (1994) reported no significant breed differences in juiciness score between Baggara and Friesian bull meat but Baggara bull had higher score for meat juiciness than Friesian crosses. Agag (1994) compared carcasses characteristic and meat yield and quality of Nyalawi and Messiria bull and reported 6.5 and 5.6 scores for juiciness score in the two breeds respectively. Gumaa (1996) found no breed differences in juiciness between Baggara and Kenana cattle that were intensively fed on grain-based diets.

2.3.4. Flavour

Flavour and aroma are defined as intrinsic meat taste components and are more affected by cooking much more than any other component of acceptability (Crocker, 1948). There is a general acceptance of the view that most constituents of meat responsible for meaty flavour are water-soluble components of muscle tissues. Species flavour and aroma are thought to arrive from materials in fat most of which were volatile when heated (Judge et al, 1989). Flavour is highly species dependant (Sink, 1979) and increases with fatness, age, breed and sex (Cole et al., 1960). Mandell et al, (1999) studied the effect of sex and breed on beef quality and reported higher beef flavour scores for steers over bulls. The
difference between Herford bulls and steers (6.06 vs. 6.11) was lower than those between Simmental bulls and steers (5.66 vs. 6.18) and they attributed that to marbling of the Herford bulls. Buckley *et al.*, (1995) reported that flavour is one of the most important factors influencing eating quality. The flavour of meat can be associated with either water in the meat or the fat component of the tissues. As the fat content of meat increases, so does flavour, thus beef from older animals is more intense flavored than meat from younger animals (Moloney, 1999).

The intensity of beef flavour was greater in grain fed beef, which was probably due in part to the effect of forage finishing on altering the fatty acids composition of beef (Mandell *et al.*, 1998). Beef flavour scores ranged from 5.11 to 5.66 for forage and grain finished beef cattle respectively.

Consumer rated overall eating quality of steak from nonimplanted steer more desirable (P<0.05) for overall eating quality than steak from implanted steers (Platter *et al.*, 2003). Smith (1990) favoured grain finished over forage finished beef due to the high scores for flavour of grain finished beef, but Course *et al.*, (1984) reported that steaks from grass fed heifers were similar to grain fed heifer steaks in tenderness, juiciness and flavour. Hankey and Kay (1988) evaluated meat quality of Angus and Charolais crossbred heifers and found no significant breed or feed differences in meat flavour. Eltahir (1994) found no breed differences in meat flavour between Western Sudan Baggara bulls and Friesian crosses. Gumma (1996) found no significant difference in flavour between beef from Kenana and Baggara bulls.
2.3.5. Water holding capacity and cooking losses

Water holding capacity is defined as the ability of meat to retain its own or added water during application of external forces such as cutting, heating, grinding, or pressing. However, some loss of moisture usually occurs even during the mildest application of these treatments because a portion of water will be present in the free form (Judge et al., 1989). Species differ in their water holding capacity as camel meat has higher water holding capacity than beef (Babiker and Tibin, 1985). McAllister et al., (1976) reported that there were no breed differences for percentage of free-water area for Polled Herford, Charolais, and Limousine and Simmental breeds. Cooking loss of meat is affected mainly by the water holding capacity (Lawrie, 1991). Meat from well-finished animal has high water holding capacity and lower cooking losses. Mohamed, (1999) found that well fattened bulls fed high energy diets revealed improved water holding capacity and reduced cooking losses. Ahmed (2003) found that bulls fed diets high in energy and high protein showed improved water holding capacity and lower cooking losses than those fed on diets with low energy and protein levels. Breed effect on cooking losses was reported by Adams et al., (1977) for Herford, Angus, Lincoln Red, Brown Swiss, Simmental, Limousine, Maine Anjou and Charolais. They found no significant variation in cooking losses of meat from those breeds. Eltahir (1994) found significant breed differences (P<0.05) in cooking losses of meat from Western Sudan Baggara and Friesian crossed bulls. The former breed was found to have more cooking losses that were associated with reduced water holding capacity. Raude et al., (1975) reported significant difference (p<0.05) in cooking losses between bulls and steers.
Chapter three
Materials and methods

3.1. Experimental animals

Forty-eight Western Sudan Baggara cattle bulls with an average initial weight of 164.1 ± 3.9 kg. Were used in the study. These animals were purchased from Central Livestock Market at Omdurman (Elmiwalih) and moved on hoof to the site of the study at the Animal Production Research Centre (Helat Kuku) Khartoum North. The animals were subjected to a pre-experimental period of 15 days during which they were offered the experimental diet. Animals were vaccinated against Rinderpest, Anthrax, Black Quarter and Haemorhagic Septicaemia. Each animal was injected with four ml of Ivomec to protect it against parasitic infestation.

Following the termination of the standardization period the animals were divided at random into four groups (twelve animals for each group) and the groups were assigned at random to four target
slaughter weights of 200, 250, 300, and 350 kg. Each group was further subdivided into three subgroups of four animals each. The subgroup was housed separately in a pen measuring (5.0 X 3.4 m$^2$) and provided with its own water and feed facilities. The animals were weighed individually after an overnight fasting except for water to determine the initial weight.

3.2 Experimental feeding:

The animals were fed molasses-based diet. The proportions of the ingredients of the diet are shown in table (1). The molasses based feed was offered *ad libitum* early in the morning. In addition the animals were offered 2 kg of sorghum stover/head daily. Green fodder *Medicago sativa* was offered at the rate of 2 kg per individual animal per week. The chemical composition of the basal diet and sorghum straw is shown in table (2).

3.3. Live animal measurements

Live animal measurements were taken according to Brown *et. al*, (1973a) and Bogg and Merkel (1984). Each animal was restricted to make sure that it was standing upright on its four hooves with its head on the normal position. The surface under the animal was hard and leveled.

A measuring tape (cm) was used for all measures with the exception of height at wither and height at rump that were measured with a calibrated stick.

The external body measurements recorded on each bull were:

1- Height at wither from the leveled ground to the highest point of wither (at the medial plane over the spinous process of the second and third thoracic vertebrae.)
2- Body length from shoulder point to pin bone.
3- Heart girth, measured around the chest at the fourth rib.
4- Abdominal circumference was taken around the abdomen at the last rib.
5- Height at hip, measured from the mid sacrum on the dorsal midline to the ground by a calibrated stick.
6- Hip width represented the distance between the lateral surfaces of the tubercoxae.

3.4 Feedlot records

3.4.1. Feed intake

Feed was offered at early morning, the difference between the weight of the quantity offered and refusal on the next morning resembles the daily feed intake. The dry matter of the experimental diet was used to calculate optimum dry matter intake.

3.4.2. Live weight growth

A Weighbridge of 1500 kg maximum capacity load with 5 kg divisions was used to weigh each bull at weekly intervals early in the morning prior to feeding.

3.5. Slaughter procedure and slaughtering

A total of forty animals were slaughtered serially (10 per group) at slaughter weights of 200, 250, 300 and 350kg. An overnight fasting period was imposed on all animals before slaughter. Slaughter weights were recorded prior to slaughter. Animals were slaughtered according to Muslim procedure (Halal) where animals were bled by cutting across the carotid arteries and jugular veins on sides as well as oesophagus and
trachea, using a sharp knife. When complete bleeding was effected, the head was removed at the atlanto-occipital joint.

3.6 Non-carcass components

External offal parts such as the hide, four feet and tail were removed and weighed. The hide was removed manually by skinning knives. The tail was removed at the first intercoccygeal articulation. The front and hind feet were removed manually with a knife at the proximal end of the metacarpus and metatarsal bones respectively and each of the external non-carcass components was weighed hot.

The carcass was opened by making ventral incision through sternum and abdomen. Gastrointestinal tract (gut) was then separated. Each of the rumen, reticulum, omasum, abomasum and intestine were weighed full and empty to obtain fill weight.

The internal organs of the thoracic and abdominal cavities were removed and weighed separately. The kidneys and their surrounding fat were left attached to the carcass.

3.7. Carcass components

The hot carcass was weighed and delivered in a chilling room for 24 hours at approximately 4°C. The chilled carcass weight was recorded. Consequently the carcass was cut longitudinally into two halves by sawing along the vertebral column. The left side of the carcass was used to collect data on carcass composition. First the Kidneys and kidney fat were removed and weighed. The left side was then quartered by cutting between 10th and 11th rib at right angle with thoracic vertebrae into fore and hindquarters and each quarter was weighed.
3.7.1. Linear carcass measurement

A measuring tape graduated in centimeters was used to determine linear measurements for carcass. The following measurements were taken:

1- Carcass length: from anterior edge of the first rib to the acetabulum branch of the pubis on the ischium.

2- Leg length: measured with a measuring tape pulled tight along the inside of the hind leg from the distal end of the tarsal bone to the stifle joint.

3- Leg circumference: taken from the anterior of the tail head passed along the rump and turned upward to the start point encircling hind leg.

4- Abdominal depth: from the spinal process of the 4th lumbar vertebrae to the most proximate edge of the flank.

5- Chest depth: from the spinous process of the first thoracic vertebrae to the midline of the sternum.

6- Longissimus dorsi muscle area: was obtained by ribbing at right angle on the longitudinal axis between 10th and 11th rib. The muscle area was traced on a transparent paper and measured by a planometre (cm²).

7- Fat thickness: was measured perpendicular to the external fat surface and constituted the average measurement of fat thickness at points (¼, ½ and ¾) of the lateral length of the longissimus dorsi muscle.
3.7.2. Carcass partitioning

Meat and Livestock Commission M.L.C, (1974) method for cutting beef carcasses was adopted. The cuts were:

Shin: separated from forequarter by cutting from elbow joint following contour of the shin bone passing through the joint and cutting across the muscle

Clod and Neck: were removed by cutting along the posterior edge of the clod bone to the blade bone joint and then proceeding in a straight line to the dorsal edge of the forequarter, then cutting to the point of removal of the shin parallel to the edge of the brisket. Cutting through anatomical seaming would separate neck from clod.

Brisket: separated by cutting along a straight line extending from a point on the 10th rib 3 inches from the join of the rib and cartilage to the anterior removal point, which was defined during the removal of the clod and neck.

Thick ribs (4bones) and Extended thin ribs (6bones). The two cuts were separated from the posterior edge of the tenth rib at a distance equal double the eye muscle length from the ventral tip of the eye muscle. The two cuts were separated from that point to a point on the first rib measured two inches from the ventral edge of the vertebral body. The thick ribs and the thin ribs were separated by a straight cut along the posterior edge of the fourth rib.

Chuck (4bones) and Extended Roasting Ribs (6 bones): Were separated from the carcass by cutting vertically along the posterior edge of the 4th rib, while the separation anteriorly was already achieved by removal of the neck and shin joints. The chuck and blade were separated
by a straight cut that extended from the 10th rib to the first rib (2 inches) from the ventral edge of the vertebral body.

Hindquarter flank: Was removed from the carcass by cutting along straight line extending from a point on the 10th rib located at a distance from the base of the rib eye muscle equal to the eye muscle length to the ventral tip of the rump muscle.

Rump: was removed by cutting along a straight line extending from a point just clear of the anterior edge of the hip bone and posterior from a point (2 inches) anterior to the aitch bone.

Sirloin: was separated from the hindquarter by cutting along the posterior edge of the 10th rib anteriorly. Separation of the sirloin posteriorly and ventrally was already achieved by the removal of the Rump and the Hindquarter Flank.

Thick flank and topside & silver: the two joints were separated anteriorly by an inscribed line two inches anterior to the aitch bone, the thick flank was then separated by cutting along the ventral edge of the aitch bone, following the counter of this bone to the ventral edge of the round bone and then a cut was made in straight line to the stifle joint following the edge of the bone. The thick flank was removed without incising surrounding muscles from the bone by cutting carefully along and under the round bone until the natural seam, which form the ventral surface of top and silver side joint.

Leg: the leg was removed from the hindquarter by cutting along a line parallel to the anterior edge and passing through the inside joint.
3.7.3. Carcass dissection

Dissection of each joint was performed by placing it on a dissecting bench and tissues were separated using scalpels and forceps. The subcutaneous layer of fats was removed. Muscles were then separated from the bones, intermuscular fats and trimmings. The different tissues were immediately placed on trays and covered with damp towels and soon weighed to the nearest gram on using an OHAUs balance. Three hours was the average time spent in dissection a carcass.

3.7.4 Sample for meat quality study and chemical analysis

Samples were taken from *longissimus dorsi* muscle, after 24 hours postmortem. Each muscle sample was equally divided into two halves. One half was used for chemical analysis and the other half used to determine meat quality parameters. Samples for chemical analysis were immediately minced and stored at –10°C a waiting analysis. Samples destined for quality attributes were allowed to oxygenate for two hours at 4°C before colour determination. Hunter Colour Component L (Lightness), a (redness) and b (Yellowness) were recorded using Hunter lab Tristimulus Colorimeter Model D25 M-2. Subsequently these samples were frozen and stored for cooking loss and shear force determination.

3.8. Chemical composition

The determination of total moisture, ash total protein and fat (ether extract) of muscle samples were performed according to the procedure described by the AOAC (1980).
3.8.1. Protein fractionation

All fractionation procedures were adopted at 4°C as described by (Babiker and Lawrie, 1983). A minced sample was weighed, put into a micro-blender jar maintained in an ice-path and 50 ml of cold 0.03 M potassium phosphate buffer (pH 7.4) were added. The content of the micro jar were blended at a low speed for 5 minutes. After homogenization, the homogenate was transferred to 100 ml centrifuge tubes and centrifuged for 20 minutes (3200 PPM). The supernatant was kept. The residue was resuspended in another 50 ml of the same potassium phosphate buffer, homogenized and centrifuged as before. The supernatant was kept and the two solutions obtained were combined and refiltered through a filter paper (Whatman No.4) to remove fats and other particule or materials not removed by centrifugation. The combined filtrate contained both sarcoplasmic protein and non-protein nitrogen fraction. Sarcoplasmic proteins were determined on one ml sample of this filterate using Buiaret method (Gornal, Baradallell and David, 1949). A thirty milliliters sample of above filtrate was mixed with 10 ml trichloroacetetic acid (20%, W/V) for 15 minutes and filtered through filter paper (Whatman No.1) to obtain non-protein nitrogen in the filtrate. Kjeldahl semi-micro method was used to determine the nitrogen content of this fraction, which was then expressed as percentage of fresh sample weight.

The residue remaining from extraction with phosphate buffer was extracted once with 50 ml of cold 1.1 MKI in 0.1 M potassium phosphate buffer (pH 7.4) using the same method of sarcoplasomic protein extraction. After centrifuge at 3500 (PPM) for 20 minutes, The supernatant was filtered through glass wool and the filtrate was used for
myofibrillar protein determination by Buijeta method. Bovine serum albumin was used as standard for making the calibration curve. The results were expressed as percentage of fresh sample weight.

3.9. Meat quality attribute

3.9.1. Water holding capacity

One-gram sample from the minced muscle was used and placed on a humidified filter paper (Whatman No.1) kept in a desiccator over saturated KCl solution) and pressed between two plexiglass plates for 3 minutes at 25 kg load. The meat film area was traced with a ball pen and the filter paper was allowed to dry. The meat and moisture areas were measured with a compensating planimeter. The resulting area covered by meat was divided into the moisture area to give a ratio expressed as water-holding capacity (WHC) of meat. A larger ratio indicates an increase in the watery condition of the muscle or a decrease in WHC (Babiker and Lawrie, 1983).

3.9.2. Cooking loss determination

Thawed samples (at 5°C for 24 hours) of *Longissimus dorsi* muscle were weighed. The samples were cooked in plastic bags placed in a water bath at 80°C for 90 minutes. Then they were cooled in running tap water for 20 minutes, dried from fluids and reweighed. The loss of weight during cooking was expressed as a percent of pre-cooking weight:

\[
\text{Cooking loss (\%)} = \frac{\text{Weight before cooking} - \text{Weight after cooking}}{\text{Weight before cooking}} \times 100
\]
3.9.3 Warner-Bratzler Shear force

For shear force and connective tissue strength determination, an Instron Model 1000 fitted with a Warner-Bratzler shear device was used. Rectangular meat samples having a cross sectional area of 1 cm\(^2\) were shorn across the muscle fibers to give shear force value of the muscle fiber. Cubical meat samples (1cm\(^3\)) were also cut from the cooked meat and used to determine connective tissue strength by shearing along the muscle fiber. Shear force and connective tissue strength were taken as means of several observations.

3.9.4 Sensory evaluation

For sensory evaluation, *Longissmus dorsi* muscle samples were allowed to thaw overnight at 4\(^\circ\)c. They were then roasted, wrapped in aluminum foil, in an electric oven at 175-180\(^\circ\)c for one hour (Griffin *et al*; 1985). Semi-trained panelists (N=6) evaluated each sample for colour and tenderness using scale of 8 points (1=extremely undesirable to 8 extremely desirable); flavour (1=extremely bland to 8=extremely intense) and juiciness (1=extremely dry to 8=extremely juicy). See Appendix (2).

3.10. Statistical analysis

The data was analyzed according to the procedure of the statistical package Stat soft (1995) as follows:-

A: -Analysis of variance was conducted to examine the effect of slaughter weight on feedlot parameters such as: overall daily feed intake, average daily weight gain, feed conversion ratio and some economical parameters of the fattening operation. Slaughter data, Carcass data and meat quality attributes.
B: - Linear regression was used to predict live body or carcass weights from external body or external carcass measurements, respectively.

C: - The allometric equation \( Y = a + b \times \) in the logarithmic form \( (\log_{10}) \) was used to study the growth rate of body parts relative to the whole.

**Table (1) Percentage composition of the ingredients of the experimental diet**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molasses</td>
<td>52</td>
</tr>
<tr>
<td>Wheat Bran</td>
<td>39</td>
</tr>
<tr>
<td>Groundnut Cakes</td>
<td>5</td>
</tr>
<tr>
<td>Urea</td>
<td>3</td>
</tr>
<tr>
<td>Sodium Chloride</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

**Table (2) Chemical composition of the experimental diet (% of DM)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Molasses feed</th>
<th>Sorghum straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>88.60</td>
<td>95.63</td>
</tr>
<tr>
<td>Crude protein</td>
<td>19.60</td>
<td>05.81</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>04.26</td>
<td>39.00</td>
</tr>
<tr>
<td>Ether extract</td>
<td>02.12</td>
<td>02.15</td>
</tr>
<tr>
<td>Ash</td>
<td>06.20</td>
<td>07.88</td>
</tr>
<tr>
<td>Nitrogen free extract</td>
<td>56.22</td>
<td>40.79</td>
</tr>
<tr>
<td>Metabolizable energy, (MJ/kg)</td>
<td>11.09</td>
<td>06.69</td>
</tr>
</tbody>
</table>
Chapter four

Results

4:1. Body measurements

The effect of slaughter weight on linear body dimensions is shown in table (3). All parameters under study increased (P<0.001) with slaughter weight. Height at wither, body length, height at rump and rump width measurements were statistically similar between bulls slaughtered at 200 and 250 kg, while body length, height at rump and hump circumference showed non significant increase between bulls slaughtered at 300 and 350 kg. The change in body dimensions with body weight increase in growing Baggara bulls is shown in table (4) and appendix (3 - 6) and is described by the equation: Y = a + bx

Data were set to represent the regression of body weight (kg) on various body measurements in (cm). The effect of live body weight on height at withers, heart girth, abdominal circumference, body length, height at rump, hump circumference and hips width were studied. For
height at wither the correlation coefficient (r) was = 0.81, with a regression coefficient (b) of 11.14 ± 1.30. The strongest correlation with live weight was recorded for Heart girth (r=0.93), with a regression coefficient (b) of 5.35 ± 0.33 increase in live weight for one unit increase in heart girth. Abdominal circumference scored a high correlation (r =0.83) and regression coefficient (b=3.52±0.37) with live weight. Body length showed moderate correlation (r=0.65) with regression coefficient (b=4.98 ± 0.95).

The linear relationship between slaughter weight and height at wither was represented by the equation: \( Y=-1011+11.14x \) (as shown in appendix 3), where \( Y= \) the weight in kg, \( x \) is the height at wither in cm. The coefficient of determination (\( R^2 \)) = 0.66 at \( P<0.001 \).
Body length had the lowest coefficient of determination \( R^2 = 0.42 \) with live weight and therefore is not reliable predictor of body weight. The relationship between animal weight and body length measured from shoulder to pin was plotted in Appendix (4) as represented by the equation: \( Y = -311.70 + 4.99 \times X \), where \( X \) is body length in cm.

The prediction line seemed to overestimate animal weight for the younger bulls in group I and group II, whereas it gave a good prediction for the third group and it underestimated the prediction of body weight for group IV.
Height at Rump was plotted against live weight as shown in appendix (5) and presented by the equation: \( Y = 10.64 \times 10^{-21} \)

The curve line overestimates values for the younger bull in (group I) and underestimated those with highest slaughter weight and it gave adequate prediction for slaughter weight for group II and group III.

The relationship between heart girth and slaughter weight was plotted in Appendix (6) and is represented by the regression equation: \( Y = 5.35x - 545.85 \), with high coefficient of determination of \( R^2 = 0.87 \) which means that 87% of the variation in body weight should be explained in term of variations in heart girth.

**4:2. Feedlot Performances:**

Table (5) gives the effect of target slaughter weight on feedlot performance of Western Sudan Baggara bulls. Target slaughter weights of 200, 250, 300 and 350 kg were attained after 36.13, 91.58, 152.52 and 220.50 days in feedlot. This implies that as the animal grows the intervals between successive weights increased significantly \( (P<0.001) \). Metabolic body weight increased significantly \( (P<0.001) \) as the slaughter weight increased. Similarly total gain increased significantly \( (P<0.001) \). On the other hand overall average daily gain declined significantly \( (P<0.05) \) as the animal increased in weight. The daily dry matter intake increased significantly \( (P<0.001) \) with slaughter weight increase. However when dry matter intake was expressed as percentage of both slaughter and metabolic body weight it declined significantly \( (P<0.001) \) as slaughter weight increased.
Feed conversion ratio increased (P<0.01), as period on feed preceded and slaughter weight increased the recorded ratio ranged from 9.4:1 kg for the lighter to 11.82:1 kg for the heavier bulls.

The linear relationship between daily dry matter intake (gm /kg $^{0.75}$) and metabolic body weight was expressed by a simple regression equation represented in Figure (1) as:

$$Y=285.39 - 2.05 x, \ R^2 = 0.99, \ p < 0.001$$

The figure revealed an inverse relationship between metabolic body weight and the percentage of dry matter intake.

Figure (2) shows the relation between daily gain (Y) and the period on feed (x) and is detected by the regression equation:

$$Y = 1.12 - 0.001x$$

The relation shows a moderate correlation coefficient ($r = 0.61$) between the daily gain and period on feed. The curve shows that during the early period on feed there was an increase in daily gain that declined (P<0.001) with the progress in the feeding period.
4:3. Costs: benefit ratio:

The economical analysis of the feedlot is presented in table (6) and (7). The cost of inputs in Sudanese dinars and as percentage of total cost revealed that the bull purchase was similar, but its percentage declined significantly (P<0.001). Absolute feed, labour, and management costs and their percentage of total cost increased significantly (P<0.001) as live weight increased. The overall cost indicated that the highest proportion of inputs costs stood for feed costs (52.57%) followed by bull’s purchase 42.89 %, then labour 3.06% and finally management 2.45%. The cost per kg live weight increased significantly (P<0.001) as live weight increased.

In table (7) the greatest revenue obtained from carcass sale constituted 94.42% of total income while noncarcass component revenue constituted 5.58% in the heaviest group. The proportion of revenue from non-carcass parts increased significantly (P<0.001) as the slaughter weight increased whereas the percentage revenue from the sale of non-carcass component declined (P<0.001). Profit and profit percentage declined (P<0.001) as the target slaughter weight increased and profit tended to be zero at 300kg live weight and thereafter it became negative. The revenue per kg live weight declined (P < 0.001) as the animal increased in live weight. Figure (3) showed the relationship between log cost and revenue on log slaughter weight where the regression coefficients of cost (b = 1.78) exceeded that of income (b=1.46), which meant that as cost increased income decreased. The intercept of the two
curves was at 300 kg live weight as shown in appendix (7) and beyond that point the benefit regressed at negative value.

Table (8) revealed the effect of slaughter weight on coefficient of private profitability, where it declined as slaughter weight increased.
4:4 Non-carcass Components

Data on non-carcass components of the experimental bulls are given in table (9). Percentage of blood from empty body weight decreased as animal weight increased (P<0.001), while that of four feet percentage declined at (P<0.05). Percentage of Genitalia increased at early stage of growth then it decreased. The percentage of the Head decline with increasing slaughter weight. Hide percentage declined slightly but the change was not significant. The percentage of omental fat increased significantly (P<0.05) as slaughter weight increased. The percentage of the mesenteric fat also increased significantly (P<0.01) as the slaughter weight increased.

There was no significant change in growth pattern for both diaphragm and empty intestine. The percentages of the tail, Lung and
trachea, rumen (empty) and total gastrointestinal tract percent declined with the increase in slaughter weight.

The percentage of the external and internal non-carcass component and that of gut fill declined as slaughter weight increased. The total weight of non-carcass component as percent of empty body weight declined as the slaughter weight increased.

The allometric relationships between the weight of non-carcass components and the empty body weight are shown in table (10). In general external non-carcass components had higher rate of growth than internal non-carcass components. The allometric growth coefficient of Four feet, genitalia, head and hide growth coefficients (b) were 0.67±0.06 (P<0.001), 0.87 ± 0.1 (P<0.05), 0.63 ± 0.05 (P<0.001) and 0.87±0.05 (P<0.05) respectively. The visceral organs such as the spleen, heart and liver had lower relative growth coefficient of 0.45±0.10, 0.59±0.06 and 0.45±0.09 respectively than EBW. The blood had relative growth coefficient of 0.48±0.04 (P<0.001). This meant that these body components increased in weight at a lower rate than empty body weight. Lungs and trachea had relatively higher growth coefficient (b = 0.77±0.07) at (P<0.01) among visceral organs. The omental fat increased at a higher rate (b=1.57±0.14), which meant it grew at a faster rate than the empty body weight. The omental fat exhibited the fastest rate of growth followed by the mesenteric fat (b=1.48±0.13), with a higher coefficient of determination (R²=0.79). Total non-carcass components had a very high coefficient of determination with empty body weight (R²= 0.93) increased in weight at slower (b= 0.67±0.03) rate than empty body weight.
External non-carcass components had the same coefficient of determination with internal non-carcass components ($R^2=90$). External non-carcass component had a higher relative growth coefficient ($b=0.75\pm0.04$) than internal non-carcass component ($b=0.63\pm0.04$).

Change in the percentage of non-carcass components relative to change in empty body weight are shown in appendix (8). All non-carcass components had negative relative growth coefficients except for the mesenteric and omental fat that revealed positive regression coefficients ($b=0.48\pm0.13$) and ($b=0.50\pm0.14$) respectively. Blood percentage showed the highest coefficient of determination ($R^2 = 0.79$) and had a negative growth coefficient ($b=-0.52\pm0.04$). Head and hide percentages showed negative growth coefficients ($b=-0.37\pm0.05$) and ($b=-0.12\pm0.05$) respectively. Genitalia percent showed the least coefficient of determination ($R^2 = 0.004$) with a negative non-significant growth coefficient ($b=-0.13\pm0.11$).

Empty gastrointestinal tract as percentage of empty body weight had a negative growth coefficient ($b = -0.40\pm0.08\ P<0.05$). The total non-carcass component percentage showed a higher coefficient of determination ($R^2=0.85$) and a negative growth coefficient ($b=-0.29\pm0.02\ at\ (P<0.001)$.

The percentage of external non-carcass component had a higher growth coefficient ($b =-0.25\pm0.04\ at\ (P<0.01)$ than that of internal non-carcass component ($b=-0.38\pm0.04\ at\ (P<0.001)$.

Figure (4) is a plot of the regression of $\log_{10}$ internal non-carcass components weight on $\log_{10}$ empty body weight in (kg).

$$Y = 0.34 + 0.64\ x$$
The equation indicated that the weight of internal non-carcass components (Y) increased as empty body weight (x) increased but at a lower rate. Growth pattern of the percentage internal non-carcass component from empty body weight is presented by the equation:

\[(\log Y = 2.20 – 0.39 \log x)\] in appendix (9)

It meant that as the empty body weight increased the percentage of internal non-carcass components decreased at a slower rate \((b = -0.39\pm0.04)\) than the empty body weight. The same trend of growth is illustrated for external non-carcass component in Figure (5):

\[\log Y = -0.16 + 0.75 \log x\]

For the external non-carcass components percentage \((\log Y = 1.84 - 0.25 \log x)\) in Appendix (10). The figure revealed that the percentage of external non-carcass components had an inverse relation with empty body weight and that they increased faster than internal non-carcass components.
Figure (6) shows the relationship of omental fat weight (kg) with empty body weight. In this figure the regression equation:

\[ \log Y = 1.56 \log X - 3.23 \]

which means that the omental fat increased in weight at a faster rate than the empty body (the growth coefficient \( b = 1.56 \)).

The relationship between the growth pattern of the mesenteric fat weight and the empty weight is shown in figure (7). The relative growth coefficient of absolute weight of mesenteric fat was \( b = 1.48 \pm 0.13 \). Like the omental fat the mesenteric fat increased in weight at a faster rate than the empty body weight. The relationship of the proportion of the mesenteric fat from the empty body weight was with the empty body weight was positive but, revealed slower rate \( b = 0.38 \pm 0.04 \) of relative growth than the empty body weight.
4:5 Carcass characteristics:

4:5:1 Carcass measurement

Table (11) shows the effect of slaughter weight on carcass measurements. All measures studied increased significantly (P<0.001) with the live weight increase. Ribeye muscle area and carcass length increase was significant (P<0.001) up to 300 kg live weight. Thereafter the increase was not significant. Leg circumference, abdominal depth and subcutaneous fat thickness showed highly significant difference (P<0.001) between bulls slaughtered at 200, 250, 300 and 350 kg. Chest circumference showed significant difference (P<0.001) between bulls slaughtered at 200 kg and those slaughtered at 300 and 350 kg but there were no significant differences between each two neighboring groups. Table (12) shows the regression of carcass measurement on carcass
weight. The leg circumference showed the highest $r=0.92$ correlation coefficient and had a regression coefficient of $(b=3.33)$. Abdominal depth and chest depth had the lowest correlation coefficient ($r=0.66$ and $r=0.68$) and consequently their predictive value is low. Subcutaneous fat thickness had high correlation ($r=0.82$) with the carcass weight. The regression coefficient $(b)$ was 19.28. Carcass length was highly correlated with carcass weight ($r=0.86$) with regression coefficient $(b)$ of 3.7 recorded. Rib eye muscle area was highly correlated ($r=0.80$) with the carcass and a regression coefficient $(b)$ of 5.6 was computed.
4.5.2. Carcass Yield

The empty body weight, carcass weight and (dressing percentage) of each slaughter weight group are given in table (13). Empty body weight increased significantly as slaughter weight increased. Hot and cold carcass weights showed the same trend as empty body weight. Dressing percentage whether calculated on live weight or empty body weight basis increased significantly (P<0.001) up to 250kg liveweight, thereafter there was a slight nonsignificant increase.
As the slaughter weight increased, shrinkage percentage decreased significantly (P<0.001). The recorded values indicated that at slaughter weight of 200kg shrinkage value was 3.24% and it decreased to 1.95% when bulls were slaughtered at 350kg.

Analysis of variance of absolute values (kg) and percentage of carcass composition is given in table (14). The absolute weight of muscle bones and fat changed at an increasing rate (P<0.01). Muscles increased from 32.06 kg in the initially slaughtered group and to 59.50 kg at the final slaughter weight. Initially bone weight was 9.72 kg and grew to reach 17.81 kg. Fat content increased in absolute values in kg (P<0.001). As percent of carcass weight muscle showed a significant (p<0.05) increase with live weight increase till 300-kg and then decreased. Bone percentage decreased at (P<0.01) and fat percentage increases with live weight increase. Muscle: bone ratio increased (P<0.01) from 3.30 for bulls slaughtered at 200kg in group I and reached 4.14 for those slaughtered at 350kg in group IV. Muscle: fat ratio declined (P<0.05) and the values recorded for the four groups were 4.00, 3.75, 3.55 and 3.34. The ratio of edible meat (muscle+ fat) to bone increased (P<0.001) with slaughter weight.
The relationship between carcass composition (muscle, bone and fats) and carcass weight are expressed in Figures (8), (9) and (10) by the regression equation:

$$\text{Log } Y = b + a \text{log } x$$

The allometric relationship of muscle weight with carcass weight is presented by the relative growth coefficient ($b=1.04 \pm 0.01$), which meant that muscle grew approximately at the same rate of the whole carcass growth, bone grew at a slower rate with a regression coefficient ($b=0.65 \pm 0.04$) and fat growth was at an increasing rate ($b=1.25 \pm 0.05$). The figure in Appendix (11) illustrates the relationship of the percentages of carcass components with carcass weight in kg. The curve revealed a minor increase in muscle percentage with relative growth coefficient of ($b=0.028 \pm 0.01$), bone percentage declined as the animal weight increased ($b=-0.369 \pm 0.04$), whereas fat percentage increased ($b=0.23 \pm 0.05$). The correlation of carcass measurement with the muscle, bone and fat is shown in Appendix (12).

The relationship between carcass weight and yield is shown in table (15). The table gives relative growth patterns of the forequarter, hindquarter, high price cuts, low price cuts, muscles, bones and fats on carcass weight as live weight increased from 165 kg to 350 kg. There were high coefficients of determination ($R^2$) for all the parameters studied. Forequarter relative growth pattern was higher ($b=1.11 \pm 0.03$) than hindquarter, which grew at significantly ($P<0.001$) lower rate ($b=0.86 \pm 0.02$) with coefficient of determination ($R^2 = 0.99$) for both forequarter and hindquarter. Low price cuts relative growth coefficient was greater than the carcass growth ($b=1.09 \pm 0.02$) while high priced cuts
increased at a slightly ($P<0.001$) lower rate ($b=0.93\pm0.01$) than the whole carcass.
The allometric relationship between carcass tissues (muscle, bone and fat) and carcass weight revealed that muscle relative growth pattern was approximately similar to the carcass ($b = 1.03 \pm 0.01$). Bone grew at a lower ($P<0.001$) rate than do the whole carcass ($b = 0.64 \pm 0.04$) and had the least coefficient of determination. Conversely total carcass fat weight showed the fastest rate of relative growth ($b = 1.23 \pm 0.05$).

Table (16) represents the relative growth pattern of prime and low price cuts throughout the experimental period. The results revealed that as the slaughter end point increased the weight of carcass quarters and wholesale cuts increased significantly ($P<0.001$).

The percentage of high priced cuts from carcass weight was higher than that of low priced cut. High price cuts percentage decreased ($P<0.01$) as the slaughter weight increased. In contrast the percentage of low priced cut increased.

Break down of forequarter into wholesale cuts revealed that the percentage of high priced cuts decreased ($P<0.05$) from 47.86% to
45.78% and consequently low priced cuts percentage increased from 52.14% to 54.52%.

The hindquarter contained the highest proportion of high priced cuts that increased in weight as slaughter weight increased. However, as percentage of carcass weight they decreased (P>0.05) with increasing slaughter weight from 77.10% to 76.11%. Low priced cuts in the hindquarter increased (P<0.001) and their percentage increased (P>0.05) as slaughter weight increased.
The composition of wholesale cuts in term of muscle bone and fat percentages is depicted in figures 11 to 24.

The percentage of clod muscles (fig 11) increased as the slaughter weight increased while bone percentage decreased and fat increased from 20.90% to 23.50%.

Figure (12) shows that the percentage of muscle tissue in the neck increased from 62.50% in the lightest group to 68% in the heaviest group. Bone percentage was 35.40% in the lighter bulls, it declined to less than half that value (15.50%) in the heavier group of bulls. Fat percentage increased from 06.30 % to 16.50%.
Figure (13) shows that the shin joint had the least percentage of muscle tissue among the forequarter cuts and the muscle increased at very slow rate as the slaughter weight increased. The proportion of bone declined slowly from 45.70% to 42.30%. This cut had the least proportion of fat, which increased by less than 1% of the joint weight.

Chuck and blade composition is given in Figure (14). The cut had a very high proportion of muscle, which increased from 70.00% in-group I to 75.70% in group IV, percentage of bone declined from 17.30% to 13.60% and separable fat was the least developed tissue and its percentage decreased as slaughter weight increased.

Thick rib composition is represented in Figure (15). The percentage of the muscular tissue increased from 75.3% to 76.40% at the final slaughter point. On the other hand bone constituted the least component and fat content changed very little and was around 18.00%.

The brisket cut composition (Figure 16) showed that there was a deposition of fat at this part of the carcass, which increased from 23.70% to 29.50% and the proportion of both muscle and bone did not change with the increase in slaughter weight.
Fig. (11) Clod (%) composition

Fig. (12) Neck (%) composition
Fig. (13) Shin (%) composition

![Bar graph showing shin composition](image-url)

- **Group 1**: Muscle: 45.7, Bone: 8.8, Fat: 9.0
- **Group 2**: Muscle: 47.7, Bone: 42.3, Fat: 9.0
- **Group 3**: Muscle: 48.6, Bone: 42.5, Fat: 9.5
- **Group 4**: Muscle: 48.8, Bone: 42.3, Fat: 9.7

Legend: Red = Muscle, Blue = Bone, Yellow = Fat
Fig. (14) Chuck and blade (%) composition

Fig. (15) Thick rib (%) composition
The percentage composition of extended thin rib composition in (Figure 17) shows that muscle percentage increased slightly, bone decreased from 21.90% to 15.90%, and fat increased from 9.4% to 15.9% as the slaughter weight increased.

In the extended roasted rib joint shown in (Figure 18) muscle percentage was almost constant between slaughter weights; bone percentage declined from 22.60 in group I to 17.50% in group IV and fat percentage increased from 15.70 to 20.00%.

Changes in the percentage composition of the leg are given in Figure (19). Muscle percentage tended to decline from 50.20% in group I to 47.30% in group IV; bone changed slightly from 38.70% to 37.80% whereas fat increased from 10.60% to 14.60%.

The thick flank joint (Figure 20) was made of a large percentage of muscles that declined slightly from 84.60% to 80.60%, as live weight increased. The percentage of bone in the thick flank ranged from 03.00
% to 02.10 % whereas the percentage of fat increased from 12.40 to 17.10%. as body weight increased.

The percentage of muscular tissue in the hind quarter (figure 21) seemed to be stable around 60.00% bone percentage declined from 06.50% to 04.80% and fat percentage increased from 31.60% in the lightest group to 33.40% in the heaviest group.

Figure (22) represents the percentage composition of joints topside + silverside. This cut had a high percentage of muscle, that increased from 73.00% to 75.50%, as the slaughter weight increased, bone percentage declined from 15.80% to 13.60% and fat percentage increased from 10.50% to 11.20%.
Fig. (17) Thin rib (%) composition

Fig. (18) Extended roasted ribs (%) composition
Fig. (19) Leg (%) composition

Fig. (20) Thick Flank (%) Composition
Composition of the rump joint is shown in Figure (23). The percentage of muscles in this cut seemed to be stable at around 64%. The percentage of bone decreased from 21.20% to 19.50% as the slaughter weight increased whereas fat percentage increased from 13.00% in the lightest group to reach 15.30% in the heaviest slaughter group.

Figure (24) shows the percentage composition of sirloin cut. Approximately a constant muscle percentage of around 64.00% was
evident in all groups. The percentage of bone decreased and that of fat percentage increased from 12% to 16%.

The regression of joints on carcass weight is shown in table (17). The relative growth coefficient of the forequarter with carcass weight is greater than that of the hindquarter. The neck joint had the fastest relative growth coefficient \( b = 1.62 \pm 0.08 \), which meant that neck joint increased in weight at a faster rate than the whole carcass. The relative growth rate of clod, chuck, thick ribs, brisket and extended roasted ribs slightly exceeded the relative growth rate of the whole carcass but the difference was not significant. The shin cut had a lower relative growth rate \( b = 0.83 \pm 0.04 \) than the carcass as slaughter weight increased from 200 to 350 kg.

All hindquarter joints with exception of hindquarter flank, had a relative growth coefficient less than unity \( b < 1 \). Leg had the least relative growth coefficient \( b = 0.59 \pm 0.04 \). Plate (1) illustrates joint wholesale cuts and their respective relative growth coefficients. The effect of slaughter weight on the absolute and percentage composition of wholesale cuts is shown in appendix (13). The relative rate of growth increase in muscle, bone and fat in wholesale cuts with carcass weight is illustrated in appendix (14).
Fig. (23) Rump (%) Composition

Fig. (24) Sirloin (%) Composition
Plate (1) Wholesale cuts with their relative growth coefficients.
4.6 Meat quality attribute and chemical composition

Table (18) presents the effect of slaughter weight on meat quality of Western Sudan Baggara bulls. As the slaughter weight increased, water-holding capacity improved significantly (P<0.001) from 3.7 for the lighter group of bulls slaughtered at 200 kg to 2.46 for the heaviest slaughter (350kg) group. The difference in water holding capacity between bull group slaughtered at 300kg and 350 kg was very small and statistically non-significant. Cooking losses decreased as slaughter weight increased up to 300 kg, thereafter it remained constant. The decrease was only significant between bulls slaughtered at 200, kg 300 and 350 kg respectively.

Warner Bratzler Shear force value increased (P<0.001) as slaughter weight of the experimental bulls increased. The shear force for the 200, 250, 300 and 350kg-slaughtered groups were 2.91, 3.20, 3.35 and 3.57 respectively. Colour, redness, lightness and yellowness data are also shown in table (18) Redness subjective scores increased (P<0.001) as slaughter weight increased. Lightness subjective scores increased and yellowness scores decreased as slaughter weight increased. Results was not significant (P>0.05).
The results on the sensory evaluation of cooked meat are summarized in table (19). Meat colour of bulls slaughtered at the lightweight was judged to be superior (more desired) over that from animals slaughtered at 300 and 350 kg. The meat from bulls slaughtered at 250 kg was also judged to have better colour than that from bulls slaughtered at either 300 or 350 kg. Tenderness subjective score declined (P<0.01) as the slaughter weight increased while flavour score increased slightly but not significant. Panelists rating of juiciness was significantly (P<0.05) higher for meat from bulls slaughtered at heavier than at lighter weights.

4:7 Chemical Compositions of Longissimus dorsi muscle

Chemical analysis of muscle is presented in table (20). Moisture content of the muscle declined (P<0.01) as slaughter weight increased. The percentage of crude protein did not change between the slaughter groups. Ether extract increased (P<0.01) with the increase in slaughter weight. Ash percentage was approximately constant in all slaughter groups.
Sarcoplasmic proteins increased (P<0.001) with the increase of slaughter weight. Myofibrillar protein also increased (P<0.05) from 11.17% in the light slaughter group to 11.61% in the heaviest slaughter group at 350 kg.

Non-protein nitrogen contents of Longissmus dorsi muscle increased with slaughter weight and the increase was only significant (P<0.05) between animals slaughtered at 350 kg and the remaining slaughter groups.
Chapter five
Discussion

5.1. Body measurements

Body measurements of heavier bulls (table 3) were significantly (P<0.001) greater than those of lighter bulls. Those changes are consequences of growth and development of the different body parts and tissues. Lawrence and Fowler (1997) stated that, body measurements, when taken sequentially over a period of time demonstrated the way in which animal body was changing, and also they might be used as predictors of animal live weight on field bases where there is no easy
access to weighing machines. The data obtained are comparable to the findings of Mohamed (1999) and Ahmed (2003). The data recorded here for height at wither; heart girth and abdominal circumference are in line with the findings of Agag (1994). But those of body length and rump width are different from those recorded by Agag (1994) for the latter measurements.

The effect of slaughter weight on body measurement was revealed by simple regression relationship in table (4). The correlation coefficients of these regressions ranged between 0.93 for heart girth (the highest) and 0.63 for body length (the least). Heart girth, abdominal circumference and rump width had higher correlation coefficients than height at wither, body length and height at rump. Sulieman et al (1990), Lawrence and Fowler (1997), and Orme et al (1959) explained that heart girth and all body width measurements were most variable with live weight because they reflect both soft and skeletal tissues growth, on the other hand length measurement reflect mainly skeletal tissue growth. Heart girth reflects body condition and in some cases the physiological status of the animal.

The regression equation to predict body weight from heart girth in this study \( Y = 5.35 \times -545.8 \) was used to predict live weight from data other than the present ones. The results are shown in table (20)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Heart girth (cm) x</th>
<th>Observed weight (kg)</th>
<th>Predicted Weight (Y) kg</th>
<th>Difference (± Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agag (1994)</td>
<td>156.10</td>
<td>286.0</td>
<td>288.80</td>
<td>2.80</td>
</tr>
</tbody>
</table>
Mohamed (1999) 140.08 207.0 203.00 - 4.00
Mohamed (1999) 144.00 206.0 224.00 18.00
Mohamed (1999) 141.00 207.0 208.60 1.60
Mohamed (1999) 141.39 206.7 210.60 3.90
Abdelhadi (2001) 141.00 209.2 208.60 - 0.60
Abdelhadi (2001) 152.30 272.3 269.01 - 3.29
Mansour (2004) 152.10 252.7 267.90 15.20

The above findings revealed that the prediction of body weight by using heart girth regression equation applied on other data of Western Sudan Baggara bulls showed the deviation between predicted and observed values. Positive values indicated under-estimation.

5.2. Feedlot Performance
5.2.1. Live weight gain

The periods taken by the experimental bulls to reach 200, 250, 300 and 350 kg live weight, were 36.13, 91.58, 152.52 and 220.50 days, respectively. Accordingly the average initial body weight (164.05 ±3.5 kg) was more than doubled the initial weight in 220 days. The growth inputs presented as gain in kg per unit time (day) revealed that the best value of daily gain (1.01kg) stood for the lightest bull slaughtered at 200kg then it declined significantly (P<0.05), as period on feed and live weight proceeded. The rate of growth of animals accelerates with time until sexual maturity is attained (point of inflection), thereafter it declines (Hammond, 1932). This might explain the decrease in live weight gain with time in the study. The decline in gain per day with advancing animal age was also reported by Fawzi and A/Rahim (1967)
for Kenana cattle, where 9 months old bulls at gained 0.9 kg/day and 20 months old gained 0.6 kg/day. This trend differed from that reported by Elshafie and McLeroy (1964) who reported increased daily gain for Baggara bulls at 18, 24, and 33 months of age. Also Gaili and Osman (1979) noted higher gain per day (1.36 kg/day) for initially heavier bulls starting at 310 kg than for lighter (155.5 kg) ones (1.13 kg/day). This could possibly be due to the greater rate of compensatory growth in older, large framed and leaner bull in the latter studies. Anderson, (1975) reported daily weight gain of 1.4, 1.3, and 1.2 kg during the growth period from 200-250, 250-300 and from 300-350 kg liveweight of temperate cattle, respectively. The comparison of the latter results with the present findings is irrelevant because of differences in environmental and other conditions.

5.2.2 Feed intake

In the current study, the average daily feed intake increased from 9.10 kg to 9.90 kg and is in line with the findings of Jepsen and Greek (1976) that the dry matter intake was positively correlated with feeding period. Consistently, Gaili and Osman (1979) noted that the daily feed intake of Western Sudan Baggara bulls of an initial weights 155 kg and 179 kg were 9.9 and 10.20 kg, respectively. Gumma (1996) also compared Kenana and Baggara bulls and reported that the dry matter intake of the two breeds increased with the increase in feeding period and lives weight. The average dry matter intake in this study is higher than that obtained by Eltahir et al (2000) and Gumma (1996) but is similar to the findings of Ahmed (2003) for the same type of cattle.
The daily dry matter intake (as a percentage of body weight) declined as live weight increased from 4.50% for the lighter group to 2.83% for the heaviest bulls. This is comparable to that found by Elkhidir et al., (1995) who reported a value of 4.40% for dry matter intake by bulls with an initial weight of 100 kg and 1.70 % for those with 450 kg live weight. The overall feed intake as a percentage of live weight in this study is in line with the results of Badr etal (1991) and Mohamed (1999). Ahmed etal (1977) and Mustafa etal (1990) reported higher daily feed intake than those of this study for Western Sudan Baggara bulls.

5.2.3 Feed conversion ratio:

Feed conversion was expressed as feed consumed per unit weight gain. The average feed conversion ratio values of the present study (table 5) ranged between 9.40 and 11.82. Feed conversion ratio deteriorated significantly with the increase in live weight possibly due to increased fat deposition, because the bulls approach mature size. Similar observations were reported by Levy et al. (1968) who noted that efficiency of feed utilization declined with increase of live weight and duration of fattening. Thiessen et al., (1984) also reported that as live weight increased feed conversion efficiency decreased and they reported values ranging from 5.52 to 13.4 for Dexter and British Charolais breeds fed on a concentrated diet. This decrease in feed efficiency with the increase in live weight was also illustrated by Gaili and Osman (1979) in Baggara bulls whose initial weights were 155, 179, 205 and 221 kg; and the corresponding feed conversion values were 8.75, 8.82, 9.37 and 9.75 respectively.
5.3. Cost: benefit ratio

Under the condition of this study bulls with average initial weight of 164±3.5 kg attained the target (market) weight of 350kg within 220 days growing at an overall daily gain of 0.89 kg.

The economical analysis of the feedlot operation (Table7) showed a decrease in profit as the feeding period increased. This is attributed to the decline in gain per day and feed efficiency. The profit tends to be zero dinars when the slaughter weight reached 300kg and changed to a loss afterwards. (Ahmed 2003) reported that the live weight gain in terms of cash money did not cover feeding cost in cattle. However this was not necessarily an indication that fattening of cattle is not profitable. The bulls under this study showed a positive feasible profit till they reached a slaughter weight of 300kg. The cost of these experimental bulls might have been more expensive in term of per capita expenses than for commercial herds. The returns may also be improved a reduction in initial cattle purchase prices.

Economists evaluate the feasibility of an enterprise according to the coefficient of private profitability (CPP), which is equal to the benefit: cost ratio. Ratio above one that means the enterprise is profitable and vice versa. The present results (table 8) indicated that bulls slaughtered at 200,250 and 300 kg produce a feasible economic value as they had a positive growth margin and coefficient of private profitability (CPP>1). Bulls slaughtered at 200 kg were the most profitable and the bulls slaughtered at 350kg were economically unfeasible.

Another way to evaluate the enterprise is to compare fattening profit and the annual national interest rate offered by banks, which was found to be 20% in year (2003) Ibnouf (2004) personal communication.
(Table 21) compares the national interest rate obtained from fattening the experimental bulls in this study.

<table>
<thead>
<tr>
<th>Slaughter wt (kg)</th>
<th>Period (Days)</th>
<th>Margin%</th>
<th>No. Of patches per year</th>
<th>Annual margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>35.7</td>
<td>33.25</td>
<td>10.22</td>
<td>339.95%</td>
</tr>
<tr>
<td>250</td>
<td>91.8</td>
<td>11.17</td>
<td>8.98</td>
<td>44.45%</td>
</tr>
<tr>
<td>300</td>
<td>152.5</td>
<td>8.77</td>
<td>3.40</td>
<td>20.95%</td>
</tr>
<tr>
<td>350</td>
<td>220.5</td>
<td>-6.75</td>
<td>1.66</td>
<td>-11.20</td>
</tr>
</tbody>
</table>

The results of table 21 revealed that the annual profit gained by bulls in the study exceeded the annual national interest for the bulls slaughtered at 200, 250 and 300 kg. The deficit only started between 153 and 220 days on feed.

5.4. Slaughter characteristics

5.4.1. Non-Carcass components

In absolute terms all non-carcass components increased in weight as the live weight increased (Table 9). Similarly, Owen and Norman (1977) reported that the absolute weight of the head; feet and lungs became heavier with increasing age. The growth of non-carcass components in the present study as illustrated by the positive relative growth coefficient (Table 10) indicate that with the exception of the omental and mesenteric fat, the percentages of all non-carcass components decreased as the live weight increased. Palsson (1955) stated that fat deposition follows a specific order for different depots and that visceral fat was deposited at faster rate than other fat deposits. Fat is
a later maturing tissue as it acts mainly as an energy reserve (Hammond, 1932, Pomeroy 1955). Jesse et al. (1976) studied the development of non-carcass component and found that the percentage made by the hide decreased from 11.20 to 09.39% and that of blood declined from 03.66 to 02.76% as the empty body weight increased from 196 to 509 kg. However Wise et al. (1961) claimed that non-carcass components are affected by proceeding age and live weight.

The growth pattern of internal and external non-carcass components as plotted in Figures (4) and (5) showed that external non-carcass components developed at a higher rate ($b = 0.75 \pm 0.04$) than internal non-carcass components ($b = 0.64 \pm 0.04$). This is partly due to the fact that internal non-carcass component contained many early maturing organs such as the heart, liver, stomachs and intestine (Hammond, 1944).

5.5 Carcass measurements

The effect of slaughter weight on carcass measurements (table 11) indicated that all carcass measurement increased ($P<0.001$) with slaughter weight. The growth pattern of ribeye area, carcass length and chest circumference showed significant increase as bulls increased in weight from 200 to 350 kg but the difference between those slaughtered at 300 and 350kg was not significant. Ribeye area in the present study is lower than that reported by Mohamed (1999). However, subcutaneous fat thickness of bulls slaughtered at 200 and 250kg in this study was similar to that reported by the latter worker. Ahmed (2003) reported carcass measurements, which were in the line with bulls slaughtered at 300kg in the present study.
The relationship between carcass weight and carcass measurement is shown in (table 12) Leg circumference had the highest correlation coefficient \((r=0.92)\) and abdominal depth the least \((r=0.66)\). Mohamed (1999) reported low correlation for most carcass measurements with carcass weight except for chest circumference, which had a high correlation coefficient \((r=0.88)\). High correlation coefficients of carcass weight with carcass length were found for rib eye muscle area, leg circumference and subcutaneous fat thickness. This agreed with the findings of Mayer et al (1965) who reported that rib eye muscle area increased linearly with the increase in live weight. Back fat thickness (measured over the Longissimus dorsi muscle) has been shown to be highly and positively correlated with carcass fat and is a useful predictor of total or percentage of fat and indirectly carcass muscle (Brungardt and Bray 1963).

The regression equations to predict carcass weight from back fat thickness and leg circumference was applied to data from other sources and found to be in the line with the findings of Mohamed (1999).

5.6. Carcass Composition

5.6.1. Dressing Percentage

The empty body weight as percentage of slaughter weight in this study (table 13) increased progressively with slaughter weight increase. This finding is in the line with Williams et al (1992) who found that empty body weight increased as body weight increased, being 85 to 95% of body weight.

The current results indicated that bulls of heavier slaughter weight dressed higher \((P<0.001)\) than those of lighter weight. As expected the
dressing percentage (of hot carcass) was greater than that of chilled carcass and is similar to that has been noted by Berg et al (1991). The latter workers reported that hot carcass dressing percentage was greater than chilled carcass dressing percentage and the results was attributed to chilling losses. The increase in dressing percentage with the increase in slaughter weight might be attributed to differences in the maturity of carcass and non-carcass components. Carcass components are late maturing and so their percentages increase as bulls get more period in feedlot, whereas the percentage of early maturing non-carcass components decline (Lawrence and Fowler, 1997). The increase in body fatness with the increase in slaughter weight could also be implicated in dressing percentage increase. Consistently, Levy et al. (1968) found that dressing percentage of empty body weight increased from 59.48 to 62.07% with the increase of body weight from 400 to 500 kg live weight. The above-mentioned results are in line with the present findings on the dressing percentage. Gaili and Nour (1980) reported dressing percentages ranging between 55 and 66% on empty body weight bases for Kenana bulls for the weight range from 100 to 400 kg.

It was noticed that the dressing percentages increased with the increase in slaughter weight. The fact that dressing percentage increased significantly as slaughter weight increased to 300kg and then the increase became nonsignificant could be explained by Preston and Willis, (1974) statement that dressing percentage increases with live weight increase till a point where it tends to cease.
5.6.2 Carcass Shrinkage

In the bulls carcasses shrinkage was significantly (P<0.001) greater in lighter animals than in heavier ones. Carcass shrinkage as percentage declined with slaughter weight to yield values of 3.24, 2.93, 2.09 and 1.95% for bulls slaughtered at 200, 250, 300 and 350 kg in that order. That was due to the direct inverse relationship between carcass shrinkage and fat content, which acts as an insulator. In this study fat deposition was greater in heavier bulls. Mohamed (1999) reported that in Baggara bulls cooler shrinkage decreased as carcass weight increased due to the increase in the amount of carcass fat that reduced moisture evaporation.

5.6.3 Carcass composition

The development of carcass tissues is represented in table (14). The weight of muscle, bone and fat tissues increased in weight. At maturity growth of muscle and bone cease, while fat continue to increase (Judge et al 1989).

The change in percentage of carcass composition revealed a slight but significant increase in the percentage of muscle tissues (P<0.01) up to 300 kg and after that it remained constant. The lower relative growth of muscle between 200 and 350kg might be ascribed to genetical causes. Muscle growth as reported by Judge et al (1989) is partly ascribed to the animal maturation rate and is the primary determinant of the age at which growth stops and the animal enters the fattening phase. Bone percentage decreased as live weight increased since bone is an early maturing tissue. Conversely fat percentage increased (P<0.01) from 8.05% to reach 19.39 % as slaughter weight increased from 200 to 350
kg. This is in line with what was reported by Swan and Lamming (1967) and Keane and More O’Ferral (1992).

The value (65%) obtained in the present study for the percentage of lean tissue compared at 350 kg favourably with the finding of Gregary et al (1994) in Limousin cattle. Keane (1994) reported that Belgian blue cattle breed had high percentage 64.70%, of muscle tissue that is in line lean percentage in the heaviest group of bulls in this study. Elkhidir et al. (1988) reported higher muscle and fat but lower bone percentage for Kenana bulls than what has been recorded for western Sudan Baggara bulls in this study. The discrepancy might be due to age and slaughter weight differences. Gaili and Osman (1979) reported 54.10%, 12.95% and 9.25% for lean, bone and fat respectively for western Sudan Baggara bulls. The latter values are lower than what was found in this study for the same type of cattle.

Muscle: bone ratio increased as slaughter weight increased and is expected because these was an increase in muscle percentage and a decline in percentage of bone, which is an early maturing tissue. In contrast muscle: fat ratio declined because the fat exhibited faster rate of relative growth than the muscular tissue. Berg and Butterfield (1968) showd that the increased muscle: bone ratio was determined by carcass weight. Waldman et al. (1971) reported that muscle: bone ratio of Holstein steers increased as live weight increased. They reported muscle: bone ratio that ranged from 2.37 to 3.73 for bulls slaughtered between birth and 590 days of age. The latter values are different from the present results on muscle bone: ratio, which ranged from 3.30 to 4.14. The discrepancy, might be due to breed or age differences. Gaili and Nour
(1980) reported muscle: bone ratio of (4.1) for Kenana bulls, which was in line with the present results for bulls slaughtered at 300 and 350 kg live weight.

Forequarter grew at a higher rate (P<0.001) than the whole carcass (b = 1.11). This might be due to the fact that the forequarter contains components such as the hump, elongated bones of the thorax, neck muscles and brisket that grew rapidly as live weight increased. The male sex hormones favour growth of neck and forequarter and might be implicated for this result as these animals are intact males.

The low price cuts grew at higher rate than the high priced cuts and the growth coefficient (b) recorded for the two groups of joints were 1.09 and 0.93. This might be due to the fact that most low price cuts were at the extremities of the animal and that most of these low price cuts are parts of the forequarter that has a higher relative growth rate than the hindquarter.

The highest growth coefficient for carcass components stands for fat tissue (b = 1.25± 0.05) (Figure 10). Bone had the lowest growth coefficient (b = 0.65 ± 0.04) and muscle growth pattern was approximately similar to the whole carcass (b = 1.04 ± 0.01) (figure 7). The pattern of development of bone muscle and fat tissues in the present study support the findings of Gaili and Nour (1980) that bone increased in weight at a slower rate, muscles at more or less the same rate and fat at much faster rate than the carcass during growth and development. On the other hand the percentage of muscle increased and that of bone decreased whereas fat percentage increased as live weight increased. Mukhoty and Berg (1971) and Warris (2000) obtained similar results and
described bones as early maturing tissues; muscles of intermediate and fat as late maturing tissue. Similar findings have been reported by Berg and Butterfield (1976).

5.6.4 Wholesale Cuts distribution:

The proportions of low and high price wholesale cuts in carcass quarters are shown in table (16). The forequarter contained higher proportion of high priced cuts than in hindquarter in agreement with (Dolezal et al, 1993). The latter worker reported that bulls and implanted steers had a higher proportion of their weights on the forequarter. In addition to that the well-developed thoracic hump in the tropical cattle could have contributed to the heavy weight of forequarter wholesale cuts (Gumma, 1996). The percentage of forequarter in this study ranged from 50.48 to 54.23% as slaughter weight increased and that of the hindquarter declined from 49.52% to 45.71%, which is in line with the findings of Kempester et al. (1976). Contrary to the findings of Thorpe and Gruickshank (1980) the percentage of the hindquarter was higher than that of forequarter in Africander, Angoni, Baroske and Boran breed of cattle. Agag (1994) studied two subtypes of Baggara cattle and reported a higher proportion of hindquarter than forequarter in both of them and that was attributed to the different procedure adopted for separating the forequarter from the hindquarter.

Carcasses of bulls under study yielded a higher amount of prime cuts than low priced cuts both in absolute and percentage terms, but as the live weight increased the percentage of high priced cut decreased and those of low price cuts increased. This might be due to the greater variability that was accounted by the development of the hump and neck
muscle in the forequarter. The latter contained most of the low priced cuts such as the neck and thin ribs that increased at fast rates (growth coefficient $b = 1.59 \pm 0.08$ and $b = 1.53 \pm 0.09$ respectively) as revealed in table (17). Excluding shin all forequarter cuts grew at a higher rate than the carcass whereas all hindquarter joints, except the flank, grew at a lower rate than the carcass.

As revealed in Figures (11) to (24) the shin and leg joints had the least percentage of muscles and the highest proportion of bones amongst all wholesale cuts. The highest proportion of muscles was found in joints such as the thick flank, thick ribs, topside and silverside, chuck and blade rump, sirloin and extended roasted ribs. Similar ranking of joints for their contents of muscular tissue have been reported by Ahmed (2003). The trend of muscle, bone and fat development in wholesale cuts followed the same pattern for carcass tissues. The percentage of muscle tissue in joints increased slightly, bone decreased and fat increased as live weight increased. A similar finding was observed by Mukhoty and Berg (1971) and Gaili and Nour (1980).

5.7 Meat Quality Attribute

5.7.1 Water holding capacity and cooking loss

Water holding capacity improved significantly as animal weight increased. That could be attributed to the increased sarcoplasmic and myofibriller proteins and to the decreased moisture content of muscles as muscle fat increased. Lawrie (1991) reported that water holding capacity improved as meat fat increased. As a consequence of water holding capacity improvement cooking losses decreased. Conversely Gumma (1996) reported better water-holding capacity values and lower
cooking losses than the present results for bulls of similar genetic constitution. The differences between results might be attributed to the fact that the bulls in the former study were carried to weights that are heavier than the present weight. The present data are in line with the findings of Mohamed (1999). Bulls in this study exhibited better water holding capacity value and lower cooking losses than what was reported by Ahmed, (2003)

5.7.2 Shear force
Shear force increased as experimental bulls increased in live weight in this study. This coincides with the findings of Romita et al, (1980) who reported that heavier animals had a trend towards less tender meat. Bailey et al, (1974) reported that meat becomes less tender as the animal advanced in age. Sharp (1962) pointed out that with increasing age collagen acquires decreasing solubility on heating and this explains the latter results. The values obtained in this study for Warner Bratzler shear force were in line with the results obtained by Ahmed (1999) who studied the effect of guar feed on beef quality of Friesian bull calves. Gumma (1996) however, reported higher shear force values for Baggara bulls the discrepancies might be attributed to the difference in age between bulls in the different studies.

5.7.3 Meat colour
The intensity of meat colour increased significantly with the increase in live weight. The colour of meat is due mainly to the concentration of myoglobin and its chemical state (Lawrie, 1978). Renerre (1982) reported that meat colour was affected by age. Jane and Pegg
(2001) explained that as the animal gets older the concentration of myoglobin increases resulting in more intense meat colour.

The intensity of red meat colour in this study ranged between 13.64 for the lighter bulls to 17.26 for the heaviest bulls. The redness value for the lighter bulls is within the range that has been reported by Mohamed (1999) for the same type of cattle. Ahmed (2003) also reported similar value to that of bulls slaughtered at 350kg. On the other hand, Ahmed (1999) reported low values for young Friesian bull calves that were fed guar as a source of protein. Breed type could be partly responsible for meat colour differences. The increase in the intensity of meat lightness observed in this study could possibly be due to the increase in meat fat with live weight increase.

5.8 Taste Panel Evaluation:

Panelists in this study assigned high colour and tenderness scores for meat from the lighter weight groups. This coincided with shear force values, which were found to increase with slaughter weight increase. Colour rating was lower for meat from heavy weight animals and this also coincided with the increase of redness intensity as live weight increased.

Flavour of meat from young animals is less strong than that from heavy weight old individuals (Lawrie, 1979). This might explain the increase in flavour intensity of meat from heavy weight bulls in this study. Juiciness was also rated high in the meat of heavy animals and that was possibly due to greater fat deposition in heavy animals.
5.9. Chemical Composition

The moisture content of the *Longissimus dorsi* muscle in this study decreased as the slaughter weight increased but protein percentage was not significantly changed. On the other hand ether extract increased and ash content did not change (P > 0.05) between treatment groups. These findings are in line with those of Callow (1962) who reported that high growth rate increased chemical fat, and decreased protein and water content of boneless carcass tissues. Reid (1972) indicated that the variation in chemical composition of the body is mainly a reflection of the variation in the fat content of the body; and here fat was found to vary great deal. Prior *etal* (1977) and Gregory *etal* (1994) reported that the decrease in moisture content was induced by a significant increase in muscle fat content. The values obtained for moisture, crude protein, fat and myofibrilar proteins in this study are in line with similar data recorded by Eltahir (1994) for meat from half-crossed Friesian bulls.

The mean values of sarcoplastic and myofibrilar proteins increased as slaughter weight increased in this study. Generally the present values are within the range reported by Gumma (1996) for the same type of cattle.

**Conclusion**
This study was concerned with beef production potentials of Baggara breed type. The cattle breed proved to have good production potential and compared favourably with some temperate beef-producing breeds. Although growth rate is determined genetically, nutritional and hormonal factors can limit growth rate. That what occurs in their natural habitat and lead to alter growth rate. This makes these animals reach market weight at older age and deteriorate both in yield and quality. It is recommended that beef intended for export or local consumption should come from animal less than three years old and be kept under feedlot to improve their finish as was adopted in this study.

Throughout the feeding period in this study Baggara bulls attained a high daily gain on molasses based diet. This high rate of gain was important factor as it determined the length of the fattening period and market weight.

Baggara bulls under studied had high carcass yield on both hot and chilled carcass weight basis. The deferential growth coefficients of body tissues revealed that muscle grew at the same rate as the whole body; bone grew at a lower rate and fat at a higher rate than the whole body. This lead to production of retails cuts with a high lean content, minimum amount of bone and suitable fat content when compared with many breeds.

Muscle tissue of light bulls had high moisture, low protein and fat content than that of heavier bulls. Improved water holding capacity, lower cooking losses, better flavour and juicy meat was reported for bulls with the heaviest slaughter weight than lighter bulls.
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EFFECT OF SLAUGHTER WEIGHT ON MEAT PRODUCTION POTENTIALS OF WESTERN BAGGARA CATTLE

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A thesis submitted in fulfillment of the
Requirements for the degree of
Doctor of Philosophy
In Animal Production

Faculty of Animal Production
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August 2004