Sudan University of Science and Technology

College of Graduate Studies

Evaluationof Nutritive Value ofYellow Maize and Sorghum {Feterita} with or without Commercial Xylam Enzyme in Broiler Diets (aComparative Study)

تقويم القيمة الغذائية للذرة الشامية الصفراء والذرة الفتريتة مع أو بدون أنزيم الزيلام التجاري في علائق الدجاج اللاحم (دراسة مقارنة)

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2015

بسم الله الرحمن الرحيم

وَلَحْمِطَيْرٍ مِّمَّايَشْتَهُونَ

الواقعة (٢١)

صدق الله العظيم

2015

Dedication

To the Soulto my Mother

Memory of my Father who have supported

Me all the way since the beginning

Of my life, and who have been a great

Source of motivation and inspiration

Finally, this thesis is dedicated to

All those who believe in the

Richness of learning

Amal

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Abstract

This study was conducted to compare the effect of feeding sorghum or yellow maize with and without commercial enzyme preparation (xylam 500) containing xylanase and amylase on performance, carcass characteristics and economic efficiency of broiler chicks. Complete randomized design under factorial arrangement (2x2) was used in this experiment. Two sources of energy {maize and sorghum grains} were replicated. 5 times with the each of the two levels of commercial xylam enzyme (0 and 500 gm/ton of diet) to formulated 4 iso-nitrogenous and iso-caloric experimental diets. Total number of 200 chicks, 7 days – old unsexed, Ross – 308 strain broiler chicks were used. The chicks were allotted randomly in 4 treatments groups 5 replicates, each of 10 chicks. All chicks were fed experimental diets for 6 weeks. Experimental parameters covered performance, slaughter and carcass data and economic appraisal.

The results of this study indicated no significant differences between broiler chicks fed on maize or sorghum based diet in body weight gain, feed intake, feed conversion ratio, mortality rate, percent of carcass dressing, giblets, commercial cuts and their of separable meat, meat chemical composition and subjective meat quality parameters. Also, there were non-significant differences noted in these parameters between the

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two sources of energy, as far as enzyme addition was concerned in this study.

The results of economic evaluation showed that, the higher net profit derived was on maize based diet, due to its lower prices in some parts of country compared to sorghum grains. Adding commercial enzyme to either maize or sorghum based diet resulted in economic benefits but, maize supplemented with enzyme is more profitable.

الملخص

أجريت هذه التجربة لمقارنة أثر التغذية علي الذرة (الفتريتة) والذرة الشامي الصفراء مع أو بدون الأنزيم التجاري الزايلام المحتوي علي أنزيمي الزيلاتيز والأميليز علي الأداء الإنتاجي ، خصائص الذبيحة والمردود الأقتصادي للدجاج اللام.

أستخدم التصميم العشوائي الكامل تحت التنظيم العاملي (٢×٢) حيث أستخدم مصدرين للطاقة (الذرة الفتريتة والذرة الشامي الصفراء) مكررة ٥ مرات مع كل من مستوي الأنزيم التجاري الزايلام (صفر و٥٠٠ مم / طن عليقة) لتكوين ٤ علائق تجريبية متماثلة في الطاقة الممثلة والبروتين الخام. أستخدم عدد ٢٠٠ كتكوت لاحم غير مجنس في عمر ٧ أيام من سلالة الروس ٣٠٨ ، متساوية تقريباً في الوزن الأبتدائي ، وضعت عشوائياً في ٤ مجموعات تجريبية × ٥ مكرارات بكل مكرر ١٠ كتاكيت. تم تغذية كل الكتاكيت علي العلائق التجريبية لمدة ٦ أسابيع. شملت قياسات التجربة ، الأداء الإنتاجي ، قيمة الصفات الكمية والنوعية للذبيحة والتقييم الأقتصادي.

دلت نتائج هذه التجربة علي عدم وجود فروقات معنوية بين الكتاكيت المغذاه علي الذرة أو الذرة الشامي الصفراء في قيمة وزن الجسم المكتسب ، كمية العليقة المستهلكة ، معدل الكفاءة

التحويلية للغذاء ، معدل النفوق ، نسب التصافي للذبيحة ، الأعضاء الداخلية ، القطع التجاربة ونسب اللحم لكل منها ، مكونات التحليل الكيميائي للحم وقياسات اللحم الأنطباعية للدجاج اللاحم.

كذلك لم يلاحظ أي فروقات معنوية بهذه القياسات بين مصدري الطاقة عندما تم إضافة الأنزيم التجاري لآحقآ في هذه الدراسة.

أظهرت نتائج التقييم الأقتصادي بأن أعلي مردود أقتصادي تم الحصول عليه كان من العليقة المحتوية علي الذرة الشامي الصفراء كمصدر رئيسي للطتقة في العليقة ، هذا وربما يعود ذلك لأنخفاض أسعارها في بعض مناطق القطر مقارنة بالذرة الفتريتة. إضافة الأنزيم التجاري سواءآ إلي العليقة المحتوية علي الذرة أو الذرة الشامي الصفراء قد أحدثت مردودآ إقتصادياً ولكن عليقة الذرة الشامي المضاف إليها الأنزيم كانت أكثر ربحية.

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CHAPTER ONE

INTRODUCTION

During the last decade poultry industry experienced rapid growth in the Sudan. The rise in poultry production and consumption may be attributed to many reasons including, increased in population, rise in living standard and change in food habits, preference to white meat and implementation of modern technology in poultry husbandry. However, the profitability of poultry industry large depends on the selection of superior commercial strains, quality economics of feeding, adoption of proper managerial practices and efficient marketing system.

In poultry management, nutrition is considered master perquisite to health production. In the Sudan feed costs about 56.7% of the total variable cost in broiler production (Elghouth *et al*., 2013). Approximately 70% of the total cost of broiler feed related to meeting energy needs (Skinner *et al.,* 1992; Abdelgadir, 2009). Thus, choosing the proper energy source and levels that will optimize growth, carcass quality and feed efficiency makes a difference.

In the Sudan, sorghum grain is predominately used as main source of energy in broiler diets. Sorghum grain is the fifth major stable cereal after wheat, rice, maize and barely. In the Sudan the sorghum rain is main stable food and comprised 80% by weight of the cereal grain grown in the country. Broiler can be fed up to 70% low tannin sorghum in combination with soybean, minerals and vitamins (Jacquin, 1991). Its nutrient composition roughly similar to that of maize and its particularly rich in starch (more than 70% of DM), CP of sorghum ranged from a to 13% DM is slightly higher than that of maize though much more variable depending in growing conditions, like maize has also low lysine and tryptophan content and its utilization may require amino acids addition. Fat content is also slightly lower in sorghum grain than maize, sorghum grain is devoid of xanthophy lin (Feedipedia, 2014). Unfortunately, the rapid growth of human population has intensified the competition between human and poultry for sorghum grains resulting in high cost of feeds and consequently high prices of poultry products in the Sudan (Ahmed *et al.,* 2013). However, the rise of the conventional feed cost demand a research for cheap resources or improving utilization of conventional feed by using some feed additives such as exogenous enzymes in order to maintain and sustain poultry production.

Maize production in the Sudan now is expanding successfully in Northern States and the two types of maize yellow and white are available and cheaper than sorghum. Maize is the most preferred source in poultry because of its high energy, low fiber, better palatability, and contain pigments and essential fatty acids (linoleic) (NRC, 1994). Maize may contains 7.1 to 9.4% CP which less than sorghum (Cowieson, 2005). Maize and sorghum have similar amino acids profile [Issa, 2009]. The nutrient composition of maize similar to sorghum for ME value in broiler chicks assay (Kriegshauser *et al*., 2006; Ahmed *et al*., 2013).

There are many anti-nutritional factors in grain sorghum namely, phenolic compounds, phytic acid and karifins, whereas maize grain contain resistance starch, non-starch poly-saccharides (NSP) and phytic acid which acts as anti-nutritional factor. These factors impair the nutrients digestion, absorption and utilization through similar but different mechanisms, there by depressed the broiler performance. (Bryden, *et al.*, 2009; Sultan, 2011; Juan, 2007). Moreover, the ideal digestibility of cereal starch rarely exceed 85% in broiler between 4-21 days of age due to physio-chemical structure of starch and interaction between starch and other components (Noy and Sklan, 1994; Wiseman, 2006). However, the supplementation of broiler feed with exogenous enzymes can improve the nutritional value of feed ingredient through the increasing the efficiency of digestion and absorption of nutrients (Meng and Slominsk, 2005, Olukosi, *et al.*, 2007, Jaing *et al.*, 2008, Selle *et al.*, 2010). The effects of exogenous enzymes can be variable and are dependent on a large number of factors such as the age of birds and the quality and types of diets (Acanovic, 2001).

The objective of this study was to evaluate the comparative performance, carcass characteristics and economics efficiency of broiler fed yellow maize and sorghum grain based diets with or without commercial xylem 500 enzyme supplementation.

CHAPTER TWO

LITERATURE REVIEW

2.1. Sorghum:

2.1.1. Scientific classification:

The Wikipedia [2014] classified the sorghum plant as follows:-

Kingdom	: Plantae
Order	: Poales
Family	: Poaceae
Sub-family	: Panicoideae
Tribe	: Andropogoneae
Genus	: Sorghum
Species	: Sorghum bicolor (L).

2.1.2. Description:

Sorghum (sorghum bicolor (L) grain is the fifth major stable cereal after wheat, rice, maize and barely. It cultivated worldwide in warmer climates and is an important food crop in semi-arid tropical regions of Africa, Asia and Central America. Sorghum grain is a small, hard caryopsis covered by glumes. In grain sorghum, panicles are compact and bear 25.000 to 60.000 seeds/kg (Ecoport, 2009). Forage sorghum yields 120.000 to 160.000 seeds/kg. The whole grain can be boiled, roasted, popped or ground to make flour bakery (flat breads) and pastry. In animal nutrition, grain sorghum is mostly used as an energy source and is a good feedstuff for poultry, pigs and ruminants. The remaining stalks can be gizzard after harvesting as some varieties stay green along time. Sorghum be grown for fodders, as a pasture or cut green to make silage and hay (Balole and Legwaila, 2006).

2.1.3. Cultivars:

Cultivated annual types of sorghum are divided into 7 agronomic groups; Kafir {South Africa}, Milo (East Africa) Feterita (Sudan) Dura (Mediterrnean area) Near {East and Middle East} Sballu (India) Koaliang (China, Manchuria and Japan) Hegari (Sudan).

Yield range from 0.5 to 0.9 t/ha in Africa, to 2.3 t/ha in China and 3.6 t/ha in USA (rained sorghum) or 4.5 to 6.5 under irrigation for hybrid types [FAO, 2009].

2.1.4. Distribution:

Sorghum is native to East Africa (likely from Ethiopia) (Ecoport, 2010) and it is though to have been domesticated around 100 BC (Balole and Legwaila, 2006). It is now widespread between 50 ºN (USA and Russia) and 40 ºS and from sea level 1000 M latitude (Ecoport 2010). Optimal growth condition for sorghum are 25-30 ºC at seedling and 30 ºC day-temp during growth, 400-750 mm annual rainfall on deep-well-drained loamy clay with pH between 5.5-7.5.

Sorghum is tolerant to drought thanks to its root system, it perform better than maize during drought and occupies areas unsuitable for maize in stress-prone semi-arid regions (FAO, 2009).

2.1.5. Nutrient composition of sorghum:

The nutrient composition of sorghum has been well doaimented (Oyenuga, 1968, ARC, 1976; Bolton and Blair, 1977, Poultry Research Centre (PRC) 1981; NRC, 1984, Tacon, 1995, Aletor, 1999; Etuk, 2008). Whole grains of sorghum contain approximately 89-90% dry matter (DM) 8.9-15% crude protein (CP), 2.8% ether extract (EE), 1.5-1.7% ash, 2.3% crude fibre (CF) and 71.7-72% nitrogen free extract (NFE)on as fed basis (Ensminger and Olentine, 1978).

Etuk *et al*., (2012) summarized the nutrient composition of whole grain of sorghum as shown in Appendices, ٢, 3 and 4.

Ensminger and Olentine, (1978) reported metabolizable energy (ME) value of 13.96, 14.04 and 13.70 MJ/kg respectively for all grains, Kaffir, and Milo type of sorghum.

Abubakar *et al*., (2006) reported a slightly lower calculated value of 12-15 MJ/kg and 12-92 MJ/kg energy for unmalted and malted sorghum, respectively. Malting increases the protein, soluble sugars and lysine and reduces tannin content of sorghum (Kubiezek *et al*., 1984. Wu and Well, 1980, Barrett and Larkin, 1974).

Khattab *et al*., [1972] reported that the protein content of Feterita, Mayo, Safra, Zerezeira, Gassabi, Abu 70 and Zinnar varied for moisture 6.4-9.6%, ash 1.3-2.8%. The protein level of 15 varieties of Sudanese sorghum varied from 6.9-12.8% and energy value from 15.13-17.15 MJ/kg (Yousif and Magboul 1972).

El-Tinay *et al*., (1979) reported the grain sorghum grown in the Sudan contain about 9.75 - 11.6% CP, 2.5-3.5% Fat, 1.2-1.9% CF, 1.70-1.72% ash and 70.8-72.9% starch.

Elamin (1992) reported that the crude protein of Feterita, Mayo, Mugud, Safara and Dabar were 14.95, 11.6, 14.85 and 11.6% respectively and the ME values were 14.46, 13.30, 14.44, 13.69 and 12.07 MJ.kg respectively.

Amir *et al*., (2009) reported that the moisture content of Sudanese (Feterita) and Indian (CSHS) sorghum cultivars were 7.49 and 6.77%, CP 14-1 and 0.02%; CF 1.65-and 1.72%, fat 3.12 and 2.84%; carbohydrates 71-46 – 77-71% ash, 2.29 and 1.54% minerals (mg/100gm), Cu 0.41 and 0.32, Ca 2.43 and 3.33, Fe 15.54 – 11.32, P 263.30 – 314.15, Na 6.18 – 5.83 and K 225.23 – 367.51, respectively.

Awad El-Kareem (2002) stated that the CP, Fat and Ash content of Sudanese sorghum (Feterita) were 13.13, 3.8 and 1.5%, respectively.
Osman [2004] recorded carbohydrates content of three Sudanese local cultivars (Talsat, Mugud and Feterita) to be ranging between 71.33 and 78.78%.

Al khair (2000) reported that the content of sorghum was 2002 Kcal/kg for ME, 13.23 for CP, 2.23 CF; 3.18 EE, 96 DM; 1.39 Ash, 71.61 NFE and Moisture was 7.04%.

Subramanium and Metta (2000) found that the CP of sorghum was 8.9; starch 72.3; sugars 1.2, fat 3.7, CF 1.2, ash 1.7 and gross energy (Cal $100g^{-1}$) 4.12.

Clement *et al*., [2010] found the CP levels are higher in millet (14.10%) and sorghum (12.75) compared to maize (10.10%).

Ibitoye *et al*., (2012) gave the ME and CP for sorghum 3270 Kcal/kg and 9.5%, respectively. The percent of ash 1.20% and CF 2.70% which one higher than that of maize.

2.1.6. Proteins in sorghum grain:

The CP contents of sorghum are higher than that of maize but about equal to wheat. The fat content of sorghum is lower than maize but higher than wheat (Magness *et al*., 1971, Atteh, 2002, Etuk *et al.,* 2012). Sorghum contains low levels of lysine but high in tryptophan content relative to maize (Purseglove, 1972, Olomue, 1995). McDonald *et al*., [2000] reported that both maize and sorghum have the main limiting indispensable amino acids, arginine, lysine, methionine, cysteine and tryptophan. However, Issa (2009) reported that the gross physiochemical characteristics of maize and sorghum are similar and these cereals have similar amino acids profile. These facts lead Rooney and Serna-Saldivar (2000) to suggest that reports of low performance in poultry and swine fed sorghum-based diets resulted from protein and starch and possibly uses sorghum with high tannin and phytate content.

Protein in sorghum is variable and ranges from 8.9 to 15% (Ensminger and Olentine, 1978) with approximately 80, 16 and 3% of the protein in the endosperm, germ and pericarp, respectively (Gualtieri and Rapaccini, 1990; Rooney and Serna-Saldivar, 2000). The major protein fraction in sorghum is the Karifins (Alcohol soluble) followed by alkali soluble or acid extractable (Bryden *et al*., 2009). Kafirins are storage proteins found in protein bodies, while glutens are localized in the protein matrix. Kafirins are characterized as -B-, and ʎ- and they comprise 70 to 80% of total protein in sorghum (Salinas *et al*., 2006). Within kafirin B- and ʎ- kafirins represents 75, 15 and 10% of the total protein (Oria *et al*., 1995). The amino acids composition of B- and ʎ- kafirins are unique because of their high content of cycteine and histidine that increase disulfide linkage formation among the different protein fractions. Kafirins also have high content is prolines glycin, glutamine, and asparagine which place them among the list of proline-rich-proteins (PRP). The PRP have 1,000 times the affinity for tannins compared to the other proteins and are thought to be the first defense in humans and other mammals adapted to high tannin food (Bulter and Rogler, 1992).

Researchers of Purdue University Developed sorghum mutants with digestibilities of protein and starch. Oria *et al*., (1995) demonstrated that the shape of protein bodies is a key factor in sorghum protein digestibility. In highly digestible sorghum proteins, transmission-electronic-microscopy revealed that - and ʌ – kafirins are localized with protein bodies. The protein bodies were irregular in shape, folded, and had numerous deep invaginations. Protein bodies of normal sorghum were spherical and contained no invaginations and the ʌ-kafirins were concentrated at the base of the folds instead of at the protein body periphery. Furthermore, Benmousa *et al*., (2006) demonstrated that the mutant line (111) has spherical starch with dense channels (i.e., many pores).

2.1.7. Starch and energy in sorghum grain:

Starch is the major proximate component (63-74%) and the major energy supplier in sorghum grain (Perez – Maldonado and Rodriguez, 2007). Starch granules consist of a linear polysaccharide called amylose (20-30% of starch) and a highly branched polysaccharide called amylopectin (70-80% of starch). Sorghum starch granules are surrounded by a protein matrix that can limit access of enzymes (Oria *et al*., 2000; Benmousa *et al*., 2006).

Other factors important to the energy value of sorghum include channels or pores on starch granules that are sites for enzyme entry (Issa, 2009), granules size, starch-lipid complexes, kafirins content (Watterson *et al*., 1993, Cao *et al*., 1998) and kernel size (Loerger *et al*., 2007). Additional factors affecting sorghum starch digestibility are waxiness and hardness. Waxy starch is more digestible that starch of non-waxy (conventional) sorghum. Unfortunately, waxy sorghum has lower yields compared to non-waxy lines (Rooney and Serna-Saldivar, 2000) and seed companies have placed no emphasis on developing high yielding waxy germplasm. Data from 280 sorghum samples in Australia revealed a range in kernel diameter from 2.4 to 4.8 mm and diameter was negatively correlated to percentage vitreousity. Vitreous endosperm contains more protein, kafirins and disulfide bonds than floury endosperm which has more soluble protein (Bryden *et al*., 2009). Cao, *et al*., (1998) reported feed: gain of 1.49 in broilers fed soft sorghum-based diets vs. 1.68 for birds fed medium and hard sorghum-based diets. The differences in kafirins structure likely contribute to the differences in bird performance reported by Cao, *et al*., (1998); Abdelrahman and Hoseney (1984) that sorghum's cross-linked kafirins cause hardness.

2.1.8. Anti-nutritional factors in sorghum grain:

Phenolic compounds:

Cheeke (1998) classified phenolic compounds as simple phenol, phenolic acid, hydrolysable tannins, condensed tannins and lignin's. All of them consist of one or more aromatic (benzene) and one hydroxyl group which enable formation cross linkage with proteins such as kafirins, cellulose and phytate. Among cereals, a unique characteristics of sorghum is having some cultivars that produce large amounts of condensed tannins. Total phenols in sorghum range from 2 to 103gm/kg, while they are negligible in corn and wheat and 14gm/kg in barely (Bravo, 1998).

Price *et al*., (1978) and Cheng *et al*., (2009) stated that white sorghum without testa or with purple testa and yellow or red sorghum without testa have very low percentage of tannin (0.0 to 0.2%), whereas, white, yellow sorghum with brown testa have medium and high tannins content (1.2 to 12.8%).

The tannins content of Sudanese (Feterita) and Indian (CSH5) cultivars were 1.19 and 0.08% as catechin equivalent, respectively (Amir *et al*., 2009). Elzein *et al*., (1992) studied the tannin content of 6 different Sudanese local varieties of sorghum rains. The results showed wide variability in tannin content of these grains ranging from 0.27% (Safra) to 0.09% (Gadarif). Chavan *et al*., (1979) analyzed two low tannin sorghum cultivars and two high tannin sorghum and recorded the tannin content for low tannin cultivars range from 0.4-0.46% (catechin equivalent) and for higher tannin sorghum ranged from 3.44 to 3.60% (as catechin equivalent).

Animal nutritionists are interested in tannin because it binds protein, carbohydrates (hemicellulose, cellulose and pectin), phytate, and minerals to form, indigestible complexes (Van Soest, 1994, Amir *et al*., 2009). The inclusion of sorghum grains high in condensed tannin (Synproanthecy anidins, AP) in poultry feeds has been shown to have negative effects on live performance of broiler chicks (Amstrong *et al*., 1974; Sell *et al*., 1984; Rubio *et al*., 1990, Nyochoti *et al*., 1997, Hancock, 2000).

These negative effects have been shown such as reduced body weight gain and feed efficiency (Douglas *et al*., 1990, Elkin *et al*., 1990) and has been attributed to the ability of tannins to bind, coagulate and precipitate protein (Bulter *et al*., 1984) including digestive enzymes through hydropholic and other interactions (Hagerman and Butler 1981) thereby reducing digestion and absorption. Owing to their a stringent taste the tannins have negative effect on feed intake, palatability and digestibility of nutrients (Hassan *et al*., 2003; Makkar, 2003; Kim and Miller, 2005) with consequent decrease in weight gain. Sell *et al*., (1984) and Nyanmabi, *et al*., (2007) agreed that tannins reduced crypt depth, intestinal wall thickness, and sucrose activity with increase mucus production. Donald *et al*., (2008) reported similar intestinal morphology for broiler chicks fed corn, sorghum and wheat-based diets although bird fed corn and wheat-based diets had better growth performance compared to those fed sorghum based diet. Nyamabi *et al*.,

(2000) stated that the incubation with sorghum proanthocyanidins reduced in vitro residual activities of amylase (70-80%) and trypsin (35-50%). In contrast Majumdar and Moudgal (1994) found that at 500 to 300mg/day tannic acid significantly increased the activities of trypsin, lipase, amylase and alkaline phosphatase in intestinal mucosa of adult chicks. Iji *et al*., (2004) supplemented maize – soy broiler diets with graded levels (0-25g/kg) of tannin derived from mimosa extract and found that increasing dietary tannin level did not influence the activities of amylase, lipase or trypsin in pancreatic homogenate, or the activities of maltase, sucvase and alkaline phosphatase in j.e. junal homogenates. These findings suggest that observed deleteriousness impact of mimosa tannin in birds were not related to inhibition of endogenous enzymes. Mole and Waterman (1987) proposed that tannin-induced reduction in proteolysis is a consequence of substrate deprivation and it has their contention that tannic acid is not able directly inhabiting trypsin activity. So while it may be premature to dismiss endogenous enzyme by sorghum derived tannin completely, the like Lihood that tannin a complexing with dietary protein is more critical issue.

Lucbert and Casting (1986) reported ME of 3.306, 3.028 and 2.888 Kcal/kg for sorghum with 0.23, 1.0 and 1.4% tannins and concluded ME decreased by 40 Kcal/kg for each 0.1% tannin above 0.23%. Douglas *et al.,* (1990) reported ME of 3.33 and 3.20 Kcal/kg for low and high tannin sorghum, respectively. As for protein utilization, when compared with corn, apparent amino acids digestibility for low, medium and high tannin sorghum was 73, 41 and 22% respectively in growing chicks, (Rostagno *et al*., 1974). However, Donkoh *et al*., (2009) reported that amino acids digestibilities of 86.2% for corn, 85.5% for low tannin (0.33 CE) sorghum and 80.6% for high tannin (1.87% CE) sorghum. Amir *et al*., (2009) reported that the in vitro protein digestibility of Sudanese (Feterita) and Indian (4) cultivars as 49.25 and 55% for uncooked sample, respectively. The lowest in vitro protein digestibility of Sudanese obtained positively correlated to its tannin content (1.19%) compared to Indian cultivars (0.08%).

It is thought that tannin provides protection for plants against fungi, bacteria, birds and herbivores (Nyachoti *et al*., 1997; Peraz-Maidonando, 2008). Menge *et al*., (2007) reported that broiler chicks can tolerate dietary tannin concentrations of 1.35% before their growth performance is compromised. Fortunately, most of cultivated sorghum do not contain condensed tannins (Hagerman and Bulter 1998; Abdoulaye *et al*., 2006) and it is well established that sorghum can be used as the sole grain source in either broiler and layer diets without compromising performance (Parthasarathy *et al*., 2005; Travis *et al*., 2006; Issa *et al*., 2007, Nyannor *et al*., 2007). However, to reduce the negative effects of high tannins sorghum, decortication, fermentation, germination and chemical treatment (i.e, HCL, formaldhyde and Alkli) are used (Beta *et al*., 2000). For Sudanese cultivar (Feterita) may be supplementation with highly rich protein concentrate increased in vitro protein digestibility (Amir, *et al*., 2009).

2.1.9. Phytate in sorghum grain:

Phytate is mixed salt of phytic acid (myo-inositol-hexaphosphate) that occurs in plant feedstuff. Digestibility of plant phosphorus in monogastrics ranges from 23 to 69% with value of 42% for sorghum grains (Wu *et al*., 2004). In addition to its ability to bind with P, phytates anti-nutritional properties include its ability to complex with protein and minerals. In contrast to tannins, sorghum phytate has not been reduced through breeding research.

Results of six conducted between 1998 to 2003 showed that total P in sorghum ranged from 3 to 4g/kg and phytate – P content ranged from 2.4g/kg (Nelson *et al*., 1968, Selle *et al*., 2003).

To improve digestibility and utilization of P from phytate, poultry producers can use phytases. Use of bacterial phytase (E-coli) or fungus phytase (A-nigers) has been shown by several researchers to enhance P utilization in poultry (Dilger *et al*., 2004; Jondreville *et al*., 2008) stated that the two enzyme types have similar efficiency in broilers Cowieson *et al*., (2004) reported reduced endogenous amino acid flow with phytase supplementation but, the reduction was greater with bacterial phytase compared to fungal phytase.

2.2. Maize:

Scientific classification:

The scientific classification of maize plant as reported by Wikipedia [2014]:-

Kingdom	:	Plantae
Order	:	Poales
Family	:	Poaceae
Sub-family	:	Ponicoideae
Tribe	:	Andropogoneae
Genus	:	Zea
Species	:	Z-mays

2.2.1. Descriptions:

Maize is a major stable food grain throughout the world, particularly in Africa, Latin America, and major feedstuff in developed countries. The maize grain has many food (gvain, flour, syvap, oils) and non-food usage (cosmetics, adhesive, paints, and varnishes). Maize starch and oil are also major products. (Ecoport, 2010). The maize grain is a major feed grain and a standard components of livestock diets where is used as source of energy. Other grains are typically compared to maize when their nutrient value estimated.

Maize breeders are created many cultivars that correspond to specific climatic or agronomic conditions and uses. “Don’t corn” maize is the most widely grown typed of maize and the one typically used for feed. Other types (Flint corn, sweet corn, flour corn) are more included for food uses. Some varieties have been created to improve the industrial values; high lysine, tryptophan, oil, amylose, low phytate etc… Brown midrib maize has lower lysine content resulting in high digestibility in livestock (Feedipedia, 2014).

2.2.2. Distribution:

Maize is native to Central America (Oaxaca Mixico) where it was demonstrated possibly as early to 10 000 BC it later spread to Central America, Caribbean, South America and North America. Thanks to genetic selection and hybridation, it now grows worldwide between 58º N in Canda and Russia and 40º S in Chile and Argentina and from Sea level to 3800 altitude in the Andean mountains (Ecoport, 2010). Optimal growth conditions are 18-21º C average day temperature, annual rainfalls superior to 750 mm, and deep well-drained rich soil (FAO, 2009).

2.2.3. Nutrient composition of maize:

The proximate analysis of common maize animal feed has been documented by (NRC, 1994, 1998, 2001; Ensminger *et al*., 1990; Mansante, 1995, 1996[a], 1996[b], 1999, 2000; Aventis, 1999; Dow 2000) as shown in appendices (5 and 6). Song *et al*., (2003) reported that maize grain cultivars may differ not only in the content, of CP but also in their starch and fibre content, as well as in nutrient digestibility and ME. Lask *et al*., (2012) evaluated the nutritive value of grain of different maize cultivars and found that the cultivars of maize differed in basic chemical composition content of amino acids and fibre fraction. The same authors found the chemical composition of different maize grain cultivars ranged as follows:-

DM, 88.8-87%; CP, 13.7-9.04%; Ash, 1.6-1.1%; EE, 5.02-1.94%; CF, 2.44-1.85%; NFE, 84.3-78.2% and gross energy 19.1-183 MJ/Kg. Also, the quality of maize produced by farmers varies greatly in all quality factors because of differences in soil, climate, disease, hybrids and management practices in regard to harvesting, drying and storing, etc… (Maier, 1995, Leeson and Summers, 1976). Blessin *et al.*, (1963) reported that chemical composition (%) of maize is moisture of 7 to 23 (average 16), starch of 61-78 (71.7), protein 6 to 12 (9.6); fat of 3.1 to 5.7 (4.3) and ash of 1.1 to 3.9 (1.4). Chopra and Sidhu (1967) reported that CP content of local Indian hybrid maize varied from 9.95-10.5%; EE, 3.61-4.58%; CF, 1.08-1.57%, and ash from 1.30 to 1.34%. Luis and Sullivan [1982] found that CP content of maize was 9.3, the amino acids, lysine was 0.25% and methionine was 0.15%.

Rao and Reddy (1986) reported that the content of the yellow maize was 9.3% for CP, 2.2 for CF, 4.2 for EE, 1.7 for total ash and 0.4% for acid insoluble ash and 63.7% for available carbohydrate. Subramanium and Metta (2000) found that the protein content of maize was 9.8% starch 71.7%, sugars 1.4, fat 5.2%, CF 1.4%, ash 1.3% and gross energy (Kcal 100^{-1}) 414. Carmencita *et al.*, (2006) stated that the CP of yellow maize, 8.91%, ME 3400 Kcal/Kg, EE 4.13, CF 1.9, moisture 11.5, ash 1.2, P 0.33 and Ca 0.002%. Panda *et al.*, (2011) compared the chemical composition of quality protein maize (QPM) with normal maize (NM) and reported that the CP content was similar between NM (8.74%) and QPM (8.90%), but the lysine (0.28-0.36% and 0.07-0.08%) was 33.57% and 33.40% higher than that of NM (0.21-0.25 and 0.05-0.06) respectively.

In contrast, the Leucine content in QPM (0.75-0.87) was 20.20% lower compared to NM (1.04-1.06%). No significant differences in gross energy were observed between QPM (4084 Kcal/Kg) and NP (4127 Kcal/Kg). Ahmed *et al*., (2013) found that the ME of yellow maize was 3340 Kcal; CP 8.5; CF, 2.84; Ash, 1.1; available P, 0.08; Lysine 0.26; methionine was 0.18%.

2.2.4. Starch and energy in maize grain:

Maize is the most preferred energy source in poultry because of its high energy, low fibre, and better palatability and contains essential fatty acids. The ratio of available energy to gross energy was higher for maize when compared with other commonly used feedstuffs (86.9, 78.9, 69.2 and 59.1) for maize, wheat, barely and oats, respectively [Summers, 2001]. The maize grain contains about 83% carbohydrates that in the form of starch, pantosans, dextrin's, sugars, cellulos, hemicellulose, starch makes up the biggest part of the carbohydrate fraction and provides most of energy. Maize grain is rich in Linoleneic acids one of the essential oil needed by poultry (OECD, 2002).

The AME_n value of maize for poultry is higher than other cereals due to its relatively high starch (620 to 720 g/kg) and crude fat (34-52 g/kg) contents. It may differ, however, depending to the level of amylose in starch (Svihus *et al*., 2005), the amylose-amylopectin ratio, the encapsulation of starch, and presence of different anti-nutrients, primarily, phytate, enzyme inhibitors and resistance starch (Cowieson, 2005). Maize starch composed of 25 to 30% amylose and 70 to 75% amylopectin (Marshall and Whelan, 1974). Maize ME is mainly affected by the quality of maize starch which is categorized into 3 classes, rapidly digestible starch, slowly digestible starch and resistance starch (Englyst *et al*., 1996).

The more rapidly digestible starch, the greater ME and quality the maize should have, whereas, the low quality maize having low ME due to slowly digestible or resistance starch (Weurding *et al*., 2001, Cowieson 2005).

2.2.5. Protein in maize grain:

Maize may contain from 7.1 to 9.4% CP, which is less than in wheat, sorghum and barely (Cowieson, 2005). The majority of the protein in mature maize grain is in endosperm and germ, however, the germ protein is superior in both quantity and nutritional quality (Vasal, 2000). The endosperm of maize contains a group of four structurally distinct alcohol soluble proteins called Zeins (Esen and Stetler, 1987).

In maize, Zeins usually account for 50-70% of the endosperm protein and are rich in glutamine, leucine and proline-zeins are essentially devoided in lysine and tryptophan and thus maize protein have poor nutritional value for monogastric. So amino acid supplementation is after necessary. Maize varieties such as Opaque-2 or Flour-2 have been designed to have better amino acids balance (Feedipedia, 2014).

2.2.6. Minerals and vitamins:

Ca and P are important minerals in animal nutrition. Maize grain is extremely low in Ca and thus, not a big contributor to the Ca in animal diets. Maize on other hand is a fair source of P, yet a substantial amount of the P is bound in the form of phytic acid (Ensminger *et al*., 1990). Other minerals such as selenium also important, but the amount in plant has been shown to reflect the amount of the mineral in soil. Nutritionist incorporate supplemental sources of Ca, P, Zn, Cu, Mn and I_2 as needed to balance broiler diets. (OECD, 2002) maize grain is a source of vit. A, E, thiamin, riboflavin, pantothenic and pyridoxine, while niacin occurs in relative high concentration, it is form of nicytin that biological unavailable (NRC 1994).

2.2.7. The anti-nutritional factors in maize:

1. Phytic acid:

Phytic acid is present in maize grain and binds about 60-75% of the P in form of phytate (NRC, 1998). Because of phytate binding, bioavailability of P in maize is less than 15% for monogastric animals. Phytic acid in maize not only reduces P availability, but also forms insoluble complexes with protein, carbohydrate, fat and some other minerals such as Ca, Fe, Mg, Cu and Zn and reduces their availability (Leeson and Summers, 2001; Rao and Reddy, 2003; Liu *et al.*, 2008[b]). Phytic acid levels in maize grain vary from 0.45 to 1.0% of DM (Watson, 1982). It is becoming comer for feed formulators to add phytase to improve the utilization of P and other nutrient (Onyango *et al.*, 2005, Bin-Baraik 2010, Elsaeed, 2013).

2. Resistant starch:

Starch is a mixture of glucans that plants synthesize as their principal reserve and consists of repeating alpha-amylose and amylopectin residues. Starch is the main polysaccharide of whole grain cereals / ranging between 468-g/kg for oats to 690g/kg for maize (Bach Knudsen, 1996). Maize is assumed to be a highly digestible cereal (Classen, 1996) and maize starch, in particular, is assumed to be completely digested by the time it exits the terminal ileum [Bedford 2002]. There is however, some evidence suggesting that starch digestibility may be variable between grain samples, even of the some cultivar (Classen, 1996) although this is not the case for maize harvested dried as in South Africa.

Noy and Sklan (1994) showed that maize starch digestibility at the terminal ileum may be as low as 85%. This may be due to the fact that some forms of starch cannot be degraded by endogenous carbohydrates (Bedford, 2002) due to their different chemical structure and physical properties (Acanovic, 2001). Such starch is known as resistant starch and presents the opportunity for the use of endogenous feed enzymes. There are three classes of naturally occurring resistant starch, RS1, RS2 and RS3 (Brown 1996): RS1 is based on the physical inaccessibility of the starch granules and is that proportion of the cereal endosperm cells that remains intact and undigested after processing. The starch contained in these cells pass through the digestive tract without being exposed to the digestive secretions and thus escapes digestion. Bedford (1996) suggested that an appreciable amount of starch escapes digestion by this rout but is most probably fermented in the intestine or caeca. RS2 is that proportion of the maize starch that is not digested due to the physical and chemical structure of the native granule especially the structure of the aif-1-4 glucose polymers that make up the starch itself (Bedford 2002). The degree of resistance to digestion of a starch granule seems to be related to the structure and conformation of the starch granule. The linear aifa-glucose polymers can be classified into two patterns (A and B). In both patterns the starch bita-glucan chains exist as left-handed, parallel-standard doubb helices. The (A) pattern however has and additional helix, occupying the centre of the hexagonal array. In the (B) pattern the centre of the hexagonal array contains water. The (A) pattern is more rapidly digested than the (B) pattern which contains a greater amount of water (Bedford 2002). While most cereals including wheat and maize posses the (A) pattern, it is known that high-amylose maize posses the {B} pattern and is thus more slowly digested (Bedford 2002). A third pattern, also resistant to enzyme degradation, is called (C) pattern and is considered a combination of the (A) and (B) patterns and are commonly found in legume starches for example pea starch. A second consideration with regards to starch granule structure is the proportion of amylose to amylopectin; the latter being more easily digested (Bedford 2002). A higher proportion of amylose results a greater RS2 content and thus a lower rate of digestion.

When starches are processed at high temperature i.e. 154-171ºC for high-amylose maize starch (Bach Knudsen, 1996), a proportion of the starch is gelatinized and no longer resistant to digestion. However, when these gelatinized structure are stored over a period of time, the can reassociate into crystalline complexes with protein, and cell wall structures and form indigestible retrograde starch known as RS3.

Starches rich in amylose are more resistant to gelatinization than amylopectin-rich starches but are more likely to form retrograde starches. Even though RS3 is impervious to pancreatic amylases it is susceptible to fermentation in the large intestine and caeca (Bedford 2002).

RS1 may thus be subject exposure to attack by cell wall-degrading enzymes to produce digestible carbohydrates while RS2 and RS3 escapes digestion but to a large extent exposed to attack by the caecal micro flora, possibly altering the caecal microbial populations [Juan, 2007].

3. Non-starch polysaccharides {NSP}:

Arabinoxylans are plant carbohydrates with arabinose and xylose Sugar components. These NSP'S Predominate in the maize endosperm, as with most other cereals although mixed linked glucans and cellulose, with glucose as sugar component, are also present (Chesson, 2001). The pericarp and seed coat are also rich in xylans, with xylose as the sugar component, and cellulose which unlike other cereals, are not extensively lignified (Chesson, 2001). Bach Knudsen (1996) evaluated the carbohydrate and lignin content of plant materials commonly used in animal feeding. The mean values of arabinose, xylose, beta-glucans and cellulose for three maize samples was found to be 22, (3+19), 30 (2+28), 1 and 22g/kg respectively. The total NSP content of maize {79g/kg} is considerably lower of hulled oats (232g/kg). The ratio of insoluble non-cellulosic polysaccharides (I-NCP) was found is be much larger for maize than for any of the other cereals evaluated (wheat, rye, barley and oats) (Bach Knudsen, 1996). This is reason the reason why maize NSP is not considered to increase digest a viscosity in broilers as it mainly soluble NSP that has water binding capacity which leads to increased viscosity. It also clear that although beta-glucans may be considered a problematic NSP_s in maize, it only contributes to 0.1% of the dry matter content of maize and to only about 1% of the NSP content there of. More problematic NSP_s in maize are the I-NCP {6.6% of DM and 63% of total NSP} and cellulose (2.2% of DM and 23% of total NSP) (Juan, 2007).

2.3. The nutritive value of sorghum and maize in broiler diets:

Elamin (1992) reported that broiler fed on 65% of either Feterita or Mugud based diets significantly ($P \leq 0.05$) showed better performance than those kept on other sorghum varieties.

Kurkur and Khire (2000) reported that broiler diets containing 25% maize and 75% sorghum and 100% sorghum caused poor growth, which may be due to high tannin content.

Carmencita *et al*., (2006) evaluate the effect of feeding different grain sources, namely, local philipinal yellow maize, US soft red winter wheat and low tannin US sorghum on the performance of broiler chicks. Grain sources for the basal diet were as follows:

Diet 1–100% yellow maize, Diet 2–100% US wheat, Diet 3-100% low tannin US sorghum, Diet 4-50% maize and 50% sorghum, Diet 5-50% wheat and 50% sorghum, the results showed in the total experiment, no significant differences were noted in the body weight gain of broiler in all cereal grains. The feed intake was significantly ($P \leq 0.05$) higher in the group fed with wheat in combination with sorghum compared to those fed with maize or maize-sorghum based diets. The feed conversion ratio (FCR) of birds fed with maize and maize-sorghum based diets were significantly ($P \leq 0.05$) higher than those fed with wheat, sorghum and wheat-sorghum diets. No significant differences were recorded in FCR of birds fed with wheat, sorghum and wheat-sorghum based diets.

Torab (2008) studied the effect of feeding sorghum (Feterita), white or yellow maize on performance of broiler. The results showed no significant ($P \leq 0.05$) differences in feed intake (FI), FCR and mortality among dietary treatments. While, the differences in body weight gain (BWG) were significant ($P \leq 0.05$) among the dietary treatments throughout the experiment, birds fed on yellow and white maize maintained significant high BWG compared to the sorghum fed chicks. In conclusion, maize could be replaced sorghum efficiently in broiler diets to support superiority meat production without any effect on skin colour of the carcass.

Amonelo and Roxas (2008) and Onimisi *et al*., (2009) reported higher BWG and better FCR in broiler fed on quality protein maize (QPM) based diets compared to a normal maize (NM) based diets.

Clement *et al*., (2010) investigated in a 42 days feeding trail the effect of replacing maize with sorghum or millet on the proformance of broiler. Four experimental diets were used in which maize (T_1) control pearl millet (T_2), low tannin sorghum (T_3), and high tannin sorghum (T_4). The result showed no significant differences in productive performance among all the treatment groups. It was concluded that millet and sorghum can completely replace maize in broilers diets.

Marshall (2011) determined the suitability of sorghum grains as an energy source in broilers by evaluating the performance of birds fed with locally available white sorghum. In 4 dietary treatments the maize components of broiler diets was substituted with sorghum at graded levels, 0, 40, 60 and 80%. A two phases feeding systems was employed. The starter phase was up to 4 weeks, and the finisher phase stretched from 4 to 8 weeks. The results showed that for the first 3 weeks, live-weigh changes between maize and sorghum based diets were not significantly different. However, from week 4 onwards, broiler fed maize diet (0% sorghum) grew significantly ($P<0.05$) faster than birds fed on sorghum based diet. FCR only showed a significant ($P<0.05$) difference between the maize-only and 80% sorghum based diet. Substituting maize with sorghum did not adversely affect total FI across all diets. It was concluded that substituting maize with sorghum by up 40% would not adversely affect broiler performance.

Kwari *et al*., (2011) investigated in the effect of replacing maize with different varieties of sorghum grown in Nigeria (Ajagama, Bulwalana, Chakalare, Kafimora and Tumbuna) on carcass characteristics of broiler chicks. The results showed that the dietary treatments had no significant effects on percents of carcass dressing, commercial cuts {thigh, breast and drumstick} and giblets (liver, heart and gizzard) except for Tumbuna variety which is showed significantly lower ($P\leq0.05$) values for carcass and organ components. The lower carcass values obtained on Tumbuna sorghum was attributed to the reduces nutrients digestibility on this diet as a result of its high tannin content (1.59%).

Adamu *et al*., (2012) studied the carcass and gut characteristics of broilers fed diets containing yellow sorghum variety replaced maize at 0, 25, 50, 75 and 100% throughout the experiment which lasted for 8 weeks. The results showed that birds fed on yellow sorghum were significantly (P>0.05) higher dressing% than those fed the control diets (100% maize). No significant differences were observed among the treatment groups in heart% and gizzard%, whearas, the liver% values were higher significantly (P>0.05) in birds fed 50% yellow sorghum compared to those fed either 25% yellow sorghum and control diets.

Ibitoye *et al.*, (2012) carried out an eight-week experiment to evaluate the growth performance and carcass characteristics of broiler chicks served 3 different sources of energy. Five diets were formulated and designed as D_1, D_2, D_3, D_4 and D_5. diets 1-(maize based) served as control, while diets 2, 3, 4 and 5 were white, red millet, white sorghum and red sorghum based diets, respectively. The results showed no significant differences (P>0.05) among the means of average BWG. The FI was significantly (P<0.05) higher in D_2 (white millet), closely followed by D_3 (red millet) than other dietary treatment. The FCR was not significantly affected by the different experimental diets. D_3(white sorghum) and D_4 (red sorghum) significantly (P<0.05) had the highest relative weight of heart, liver, kidney and small intestine compared to the other experimental diets.

Ahmed *et al.*, (2013) studied the nutritional value of yellow maize when it substitutes sorghum grains as source of energy at levels 0, 25, 50, 75 and 100% in broiler ration. Five diets were formulated as follows: Diets (S_0) containing sorghum 100% (control, 60% of the diet; Diet (S_1) 75% sorghum; 25 maize, Diet (S_2) 50% sorghum, 50% maize, Diet (S_3) 25% sorghum, 75% maize and Diet (S_4) maize 100%). The experiment was lasted for 6 weeks, the results showed significant increase (P<0.01) in FI and BWG for birds fed diet. S_0, S_1 and S_2, respectively no significant differences were observed in FCR among all dietary treatments.

Moreover, protein efficiency was greater for birds received but S_4. All the treatments had no significant (P>0.05) effect on cold dressing %, liver and abdominal weight. The cost of production decreased by increasing level of maize.

Kwari *et al*., (2012) conducted A 9-week experiment to assess the effect of feeding low tannin sorghum grain as a replacement for maize on growth and carcass measurements. The experimental diets used contained sorghum grains at 0, 25, 50, 75 and 100%, respectively as a replacement for maize. The results of growth performance showed no superiority of maize over sorghum grain in terms of BWG and FCR throughout the experimental period. Feed sorghum had no adverse effect on the yield of carcass, cut-up parts or weight of vital organs (heart, liver and spleen). It was concluded that low tannin sorghum can completely replace maize in broilers diet without compromising the growth, meat yield or health.

Tulasi *et al*., (2004) studied the effect of replacing maize with sorghum grains on the performance of broilers. Grains from 4 improved sorghum bicolor cultivars (CSH16, CSV15, PSV16 and S35) and one traditional yellow variety were used to replace maize (control diet) in the starter (1-4 weeks) and finisher ration (5-6 weeks) of broilers by 50, 75 and 100% levels. The results indicated that the BWG and FI of broilers were statistically similar in sorghum diets at all inclusion levels compared to control diet. However, the feed conversion efficiency of broilers was significantly (P<0.05) higher in the 100% sorghum diets compared to maize diet. In conclusion, the inclusion/replacement of sorghum in maize diets improves the FCR and decreases the total feed costs in broiler production.

2.4. Enzyme supplementation in poultry diets:

The supplementation of poultry feed with exogenous enzymes can improve the nutritional value of feed ingredients, increasing the efficiency of digestion. Since the mid 1980_s, feed enzymes have dramatically improved the profitability of commercial poultry production. The current feed enzymes market is worth an estimated $ 700-800 million USD (Bao, *et al*., 2013).

The availability of nutrients in feedstuffs is often limited by presence of anti-nutritional factors. Six anti-nutritional factors have been identified in plant protein such as soybean (Huisman and Tolman, 1992). The first group of factors contains a depressive effect on protein digestion and on the utilization of protein such as protease inhibitors, lecithin, phenolic compounds, and saponins. The second group factors have negative effect on the digestion of carbohydrates as amylase inhibitors, phenolic compound, non-starch-poly-saccharides (NSP), and flatulence factors. The third groups of factors consist of negative effects on the utilization of minerals such as glucosinolates, phytic acid, oxalic acid and gossypol. The fourth group of factors inactivates vitamins, or causes an increase in the animal vitamins requirements.

The fifth group of factors stimulates the immune system that may cause damaging hypersensitivity reaction such as antigen proteins. The six groups of factors in feed have ataxic effects such as lectins and cyanide-containing compounds (Lusas, 2000). Moreover, there are many other important demands for use the exogenous enzymes (Johnson *et al*., 1993). First, there is an increasing shift in the use of alternative feedstuffs in formulating diets. Second, the use of enzymes has been known to be effective against particular dietary components. Third, novel by-products such as wheat bran and linseed meal have a depressing effect on growth. Fourth, there is introduction of excreta pollution control by governments, examples which include phytase and protease reducing excretion of P and N (Francesch *et al*., 2005). Fifth, there are indirect physiological actions on problems on problems of commercial importance, for example the reduction of sticky litter in poultry fed on cereal contain high levels of NSP (Lee *et al.*, 2009 and Santos *et al.*, 2004). Six, there is reduction of broiler performance due to Bann the use of antibiotic as growth promoter by EU Since 2006. (Eckert *et al.*, 2010).

2.4.1. Amylase:

Theamylase family of enzymes has been used in a number of industrial processes such as feed fermentation, textites, paper industries, feed industries, etc… The main classes of amyloses act on starch, which include alfa-amylose (EC 3.2.1.1), bita-amylase (EC 3.2.1.2), and gluco-amylase (EC 3.2.1.3).Alf-amylase randomly splits alfa-1, 4- glucosidic bonds between adjacent glucose units in linear amylose chains, while gluco-amylase hydrolyzes single glucosidic residues from the non-reducing ends of amylose and amylopectin in step-wise manners.

Gluco-amylase also hydrolyzes the alfa-1, 6– linkages in the branching points of amylopectin at a slower rate as compared to alfa-1, 4- linkages (Xiaolun, 2007).

Alfa-amylase has a molecular weight (MW) range of 50 KD, and requires Ca^{tt} stability and activity. The optimum pH varies depending on the enzyme source (6-7 for mammalian, 4.8-5.8 for Aspergillums oryzea, 5.85-6 for Bacillus subtitles, 5.5-7 for B. Licheniformis).

Optimum temperature for activity various from 70-72ºC for alfa-amylase produced by B. subtilis and 90ºC for the enzymes from B. Licheniformis (Nutrex, 2000).

Starch has always been considered as highly digestible (98%). However, it seems that only about (82%) of the starch present in raw materials is digested in the small intestine. The undigested starch reach's the large intestines, where it is fermented by the gut flora; this fermentation process includes the production of volatile fatty acids. After absorption, the voitile acids supply energy to the animal. However, this mechanism is energetically less efficient than the enzymatic digestion (Bao *et al*., 2013) an additional amounts of exogenous Alfa-amylase can certainly positively influence the utilization of energy from cereals (Pourreza *et al*., 2007). Also the young animals for example day-old chicks the endogenous production of digestive enzymes increases slowly, starting at with Wiseman (2006) suggested that poor digestibility values for starch in young broilers are attributed to physio-chemical structure of starch and interaction between starch and other components in some ingredient. However, Jiang *et al*., (2008) indicated that the exogenous amylase improves productive performance of young chicks by compensating the digestive system of the birds.

2.4.2. Xylanase:

Plant cell walls mainly composed of cellulose 40 to 45%; hemicellulose 30 to 35% and lignin 20 to 23%, cellulose and hemicellulose are the major plant structural polysaccharides (Ladish *et al*., 1983). Cellulose is a linear polymer of glucose linked by β-1, 4-glucosidic bonds with simple primary and complex tertiary structures. Based on the main sugar residues present in the polymer backbone, hemicellulose can be termed xylans, glucomannans, galactans or Arabians with xylans and glucomannans being the two types of hemicellulose (Timell, 1967). Xylans from annual plants, called arabinoxylans, are more heterogenous as compared to xylans from perennial plants. The two major types of arabinoxylans are highly branched without uronic acid substitution in cereal endosperm and much less branched substituted with uronic acid and/or with 4-0-methyl ether and galactose in lignified tissues. Arabinoxylans of giamineous plant contain a cetic and phenolic acids (ferulic, P-Coumaric) which are esterified to the backbone units and arabinose side group, respectively (Hartley and Ford, 1989).

Hemicellulose can be converted to soluble sugars by enzymes, mainly of microbial origin termed hemicellulose (Suurnakki *et al*., 1997). The main enzymes involved in breakdown of the hemicellulose backbone are endoxylanases (xylanases) and endomannanase (mannanase) to hydrolyze xylan and mannan, respectively (Franco *et al*., 2004). Xylobiose, xylotriose and substituted oligomers with two to four residues are released.

Other hemicelluloses, including bita-xylosidase, bita-mannosidase, alfa-L-arabinofuranosidase, alfa-D-glucuronidase, alfa-glactosidase, acetyland phenyl esterases, remove side-chains and substituents (Shallom and Shoharn, 2003). In general, xylanases specifically hydrolyze the internal bita-1-4 linkages of polymetric xylan and are called endoxylanases. Based on their action on different polysaccharides, endoxylanases have been classified as either specific or non-specific (Sunna and Antranikian, 1997). The specific endoxylanases breakdown xylans at only bita-1, 4 linkages, while non-specific endoxylanases hydrolyze bita-1, 4-linked xylans, bita-1, 4-linkages of mixed zylans and other beta-1, 4-linked polymers such as carboxymethyl cellulose. Xylanases are inhibited by the presence of high concentrate of their hydrolysis products. For example, endoxylanases are believed to be inhibited by high concentrations of zylobiose but not by xylose. In general, activity of xylanases is neither activated nor inhibited by metal ions and reducing agents (Birsan *et al*., 1998).

Various reports in the literature suggest the efficacy of xylanase to improve nutrient digestibility and performance in rye (Danicke *et al*., 1999; Silva and Smithard, 2002); wheat (Choct *et al*., 1999, Marron *et al*., 2001) and barely (Brenes *et al*., 1993) based diets for broilers. The use of xylanase only in maize or sorghum based diets is less well documented. However, it was found that supplying an enzymatic cocktail including xylanase improved the nutrient digestibility and productive performance of broiler fed maize-based diet (Zanella *et al*., 1999, Cowieson and Adeola, 2005) or sorghum based diet (Wyatt *et al*., 1997; Selle *et al*., 2010). Undoubtedly these results suggest positive response of xylanase although the improvement seen may be attributed to the combination of xylanase with other carbohydrates and protease.

2.5. Response of broiler chicks fed on maize or sorghum based diets supplemented with microbial enzymes:

2.5.1. Maize:

Zanella *et al*., (1999) found that addition of 0.1% Avizyme (a product containing mixture of xylanase, amylase and protease) to maize-soybean meal based diet resulting in a significant improvement in digestibility of CP (+2.9%), Starch (+1.8%) and Fat (+1.6%).The metabolizable energy {ME} of the tested diet also significantly improved (+2.54%) by enzyme addition.

Cowieson and Adeola (2005) found that an enzymatic cocktail exhibiting xylanase, protease and amylase activities to maize – soybean diets improved gain-to-feed ratio and BWG although the effect of the enzyme combination an ileal digestible energy (IDE) and digestibility coefficients of N and dry matter (DM) were dramatic.

Meng *et al*., (2005) reported 2.3% and 5.5% an increase in dietary apparent metabolizable energy and CP content, respectively upon supplementing a maize-soybean based diet with a combination of xylanase, glucanase, pectinase, cellulose, mannanase and galactanase enzymes.

Saleh *et al*., (2005) found 2.4% and 4% increase in AME and apparent ileal CP digestibility, respectively when they supplemented a maize-soybean based diet with a mixture of enzymes included xylanase, cellulose, bita-glucanase and hemicellulose.

Cowieson *et al*., (2006[b]) stated that the addition a combination of amylase, xylanase and protease and phytase enzymes to the maize-soybean based diets improved the growth performance and digestibility of P, Ca and amino acids of broiler chicks.

Olukosi *et al*., (2007) studied the response of broiler chicks to cocktail of xylanase, amylase and protease (OXAP) when fed a nutritionally margin in P and ME – maize-soybean based diet. The results showed that XAP was effective in improving ileal N and P digestibility, but had no effect on ileal digestible energy. The results also showed that chicks beneficial more from enzyme addition at younger age and that the contribution of the enzymes on nutrient retention was decreased with the age in chicken.

Juan (2007) evaluated the effect of multiple-enzymes combination in mash and pelleted vegetarian maize-soybean diets in terms of apparent excreta and ileal-N and amino acids digestibility. The results showed that addition of multiple enzymes improved the apparent excreta-and ileal-N digestibility of the mash diets during the period 14-21 days, and the ileal-N digestibility of the pelleted diets at 28 and 35 days of age. The digestibilities of threonine, methionine and pheylalanine (14-21 d) and cysteine (22-28 d and 29-35 d) were improved by addition of the enzyme combinations to the mash diet. Over the entire experimental period (14-35 d) the ileal digestibilities of histidine, cysteine and leucine of mash diets were improved by 0.2, 0.2 and 1.9%, respectively, following enzymes addition.

Lee *et al*., (2010) reported that BWG and FCR improved ($P<0.05$) in chicks that were fed low energy maize-wheat-sorghum diets supplemented with multiple enzymes (xylanase, glucanase and phytase) than those received the control diets during the finisher period (22-32 d) and the entire experimental period (1-32 d). The carcass parameters were not affected by the addition of enzymes.

Hajati *et al*., (2009) found that addition of multi-enzymes (xylanase and beta-glucanase) to broiler maize-wheat-soybean based diets at level 500mg/kg significantly (P<0.05) improved BWG, FCR, relative growth, energy and protein efficiency from 11-28d of age. Adding enzymes significantly (P<0.05) increased BWG, decreased FI and improved FCR from 29-42d of age: Enzymes inclusion significantly (P<0.05) increased carcass dressing, thigh and drumstick percentages at 44d of age.

Neill and Liu (2011) investigated the effect of a commercially available xylanase on the growth performance of starter broilers fed diet containing maize of one variety, harvested in different five geographically regions in China. The results showed there was no effect of harvest region on the FT, BWG and FCR of broiler over 18d periods. There was a significant (P<0.05) improvement in all parameters with addition of xylanase enzyme.

Amoni *et al*., (2011) evaluated the effect of commercial enzyme preparation (xylem) containing xylanase and amylase on performance of broiler chicks fed maize-soybean diets with various levels of ME. Three diets were formulated with ME contents being 3000, 2900 and 2850 Kcal/kg for growing (14-23 days); 3100, 3000 and 2950 Kcal/kg for finishing (24-32 days) and 3200, 3100, 3050 Kcal/kg for withdrawal (33-40 days) period. Diet (1) fed without enzymes (control diet), Diets (3) and (3) were fed without or with 0.5kg/ton of xylem. Results showed no significant differences among dietary treatments on BWG for growing period. Meanwhile, birds fed diet (3) of the lowest energy level with enzyme inclusion gained more BWG compared to birds fed the other diet at finishing, withdrawal and overall periods. However, birds fed diet (3) with enzymes addition significantly (P<0.05) consumed less feed than those fed control or low energy diets (diets 2 and 3) without enzymes at growing period. The best FCR values were obtained for birds fed low energy diets (diet 2 and 3) with enzymes inclusion. Worse FCR values were obtained for birds fed low energy diets without enzyme supplementation. The carcass characteristics were not affected by treatments.

Nian *et al*., (2011) reported the supplementation of microbial xylanase had no effect on BWG and FI of broiler fed maize-soybean diets. But FCR was improved significantly ($P>0.05$) by 4.3% with supplemental xylanase.

2.5.2. Sorghum:

Wyatt *et al*., (1997) reported that addition of Avizyme (xylanase, amylase and protease) to sorghum-soybean meal based diet improved BWG and corrected feed conversion ratio by 5 to 16 points over three experiments and allowed for a reduction in diet specifications by 3% without adversely affecting broiler performance.

Pack *et al*., (1998) reported that the combinations of enzymes contained xylanase, amylase and protease improved feed efficiency by 6.5% and tended to increase BWG by 5.7% in male broilers offered sorghum based diets from 1-42 days. Also all nutrients digestibilities were improved by enzymes addition.

Cadogan *et al*., (2005) reported that the inclusion of xylanase, amylase and protease combinations in sorghum based diets significantly ($P<0.05$) increased BWG by 3.7% and FI by 4.9% from 1-21 days, but, significant response were not observed from 22-42 days post-hatch.

Selle *et al*., (2010) studied the influence of two enzymes preparations in sorghum based broiler diets on growth performance and nutrients utilization. One preparation (Enzyme A) blind of enzymes contain xylanase, protease and bita-glucanase activities, while the second

(Enzyme P) contained only xylanase activity. Sorghum based starter (1-14 days) grower (15-28 days) and finisher (29-42) diets without or with either enzyme A or enzyme P were offered to broilers from (1-42 days) post-hatch. The results indicated that enzyme P numerically depressed feed efficiency, whearas enzyme A marginally enhanced feed efficiency and increased BWG by 6.7%, which closely approached significance ($P<0.06$). The enzymes addition did not influence nutrient utilization of AME, N-retention and N-corrected AME (AMEn).

Makkawi, (2009) examined the effect of addition commercial enzyme product xylem 500 (xylanase and amylase) to sorghum-groundnut and seseame cakes based diets under two ME 3000 and 3200 Kcal/kg on the performance and carcass characteristics of broilers. The results showed that the performance and carcass characteristics were not affected significantly ($P>0.05$) by the enzyme supplementation.

Bin-Baraik (2010) tested the effect of adding commercial enzyme xylem 500 to sorghum-wheat bran-groundnut and sesame cakes based diets on performance and carcass yield and meat quality of the broilers. The result indicated the addition of commercial enzyme xylem 500 to the diets improved significantly ($P<0.05$) the BWG, FI and FCR values of the broiler chicks throughout the experimental periods (6 weeks). The addition of enzyme had no significant effects on the percent’s of carcass dressing, giblets, and commercial cuts and their separable meat, meat chemical composition and subjective meat quality parameters of broiler chicks.

El-Saeed (2013) stated that inclusion of commercial microbial enzyme xylem 500 to the broiler diets based on sorghum-prosopis pods-groundnut and sesame cakes improved significantly ($P<0.05$) BWG, FI and FCR values of broiler chicks during the experiment periods {6 weeks}. No significant differences were observed among treatment groups in all carcass yield and meat quality parameters.

Sultan (2011) conducted 3 experiments to study the influences of addition xylanase, protease and phytase individually or in combination in broiler sorghum based diets on the nutrient digestibility. The first experiment exmined effect of xylanase, protease and phytase and their combinations in 8 bioassay diets (including control diets) on the digestibility of starch, protein, amino acids and AME of sorghum during starter (days 14-21) and finisher (days 35-42) phases of growth. During the starter phase digestibility of coefficients of all the nutrients were significantly (P>0.05) improved by all treatments except xylanase that only numerically improved ileal protein and amino acids digestibility. The response was greater with enzymes combinations. In the finisher phase the qualitative trends enhancing nutrient digestibility of sorghum by broilers in different treatment were similar to those observed in the starter phase but the extent of improvement was less. In the second experiment the efficacy of dietary enzymes (used in the first experiment), on nutrient digestibility of a red (MR Buster) and a white (Liberty) sorghum variety was undertaken using 6 bioassay diets.

Responses to enzymes were different between the red and white sorghum AME of red sorghum was greater irrespective of enzyme treatments and was maximized with combination of phytase + protease. The combination of xylanase + protease gave the greatest improvement in white sorghum. In the third experiment the effect of xylanase, protease and phytase on small intestinal digestion of sorghum was examined in 42 day-old broilers.

The starch digestibility rate was highest with protease and was not significantly different from phytase but was significantly (P>0.05) higher than xylanase and the control group. The AME was significantly higher in the phytase and protease groups followed by xylanase.

CHAPTER THREE

MATERIAL AND METH ODS

3.1. The study was conducted to the performance, carcass characteristics and economic efficiency of broiler chicks fed on sorghum or maize based experimental diets with or without exogenous commercial enzyme (xylam 500) supplementation. The experiment was carried out in the PoultryFarm at Kuku Poultry Research Centre – Khartoum North; during the period from 29th July to 9th September – 2012. The ambient temperature averaged (26-39°C) during the experimental periods (Appendix I).

3.2. Experimental chicks:

A total number of 200 chick's day-old of Ross-308 commercial unsexed broiler chicks strain were purchased from Salsabeel Company and transported to the Poultry Farm of Kuku Poultry Research Centre. The chicks were adapted to the house environment and feed over 7 days before start the experiment. At the end of adaptation period, all chicks were weighed with an average initial weight of 180gm. The chicks were then assigned randomly into 4 dietary groups A, B, C and D in completely randomized design under 2x2 factorial arrangements. Each group was divided into 5 replicateseach of 10 chicks. Ground brooding/rearing system was adopted for 6 weeks experimental period chicks were bought vaccinated against Marek's disease in hatchery. On farm the chicks vaccinated against Gumboro disease at 11 days of age and Newcastle at 22 days of age, soluble multivitamin compounds (Pantominovit – Panter – Holland B.V. 5525 ZG Duized Holland) and antibiotics (Neomycin, Avico, Jordan) were given to the chicks before 3 days of the vaccination, and 3 days after vaccination in order to guard against stress.

3.3. Experimental diets:

Two energy sources (maize and sorghum) were used with two levels of commercial enzyme xylam 500 (0 and ½ kg/ton diet) to formulate 4 iso-nitrogenous (22.7 CP) and iso-caloric (3100 Kcal/kg ME) experimental diets A, B, C and D being adequate in all nutrients [**Table 1, and 2**] matching broiler chicks requirements according to NRC, 1994. The commercial enzyme preparation (xylam 500) used in the present study was produced by Nutrer Company. Xylam 500 is a bacterial enzyme preparation produced from Bacillus subtilis and Bacillus amyloliquefaciens. It contains 1.260 u/g endo-1, 4 beta – xylanase and 8.00 u/g aifa – amylase.

3.4. Housing:

An open wire mesh – side poultry house was used. The house was constructed of brick wall 50 cm high, the rest of the wall to the ceiling was made of wire netting on all sides, the roof was made of corrugated iron sheets supported with iron posts. Twenty pens, I m^2 each, inside the house were prepared using wire mesh partitioning. Each pen was equipped with one feeder and drinker to allow *ad libitum* consumption of feed and water. Light was provided 24 hours, in a form of natural light during the day and artificial light during night. Five bulbs (60 watt) were used for this purpose. The house was cleaned and disinfected before commencement of the experiment.

3.5. Data collected:

Performance data:

Average body weight, weight gain and feed consumption (g) for group were determined weekly throughout the experimental period. Health of the experimental stock and mortality data were closely observed and recorded daily.

Slaughter procedure and data:

At the end of the 7th week the birds were fasted overnight with only water allowed. Birds were weighted individually before slaughter by severing the right and left carotid and jugular vessels, trachea and the esophagus. After bleeding they were scalded in hot water, hand-plucked and washed. The head was removed close to skull and feet and shanks were removed at the hock joint. Evisceration was accomplished by a posterior ventral cut to completely remove the visceral organs. Hot carcass and each organs, heart, liver and gizzard were separately weighed

Carcass data:

The hot carcass was prepared for analysis by removal of the skin and neck near the body. The carcass was then divided into right and left sides by mid sawing along the vertebral column and each side was weighed. The left side was divided into three commercial cuts; breast, thigh and drumstick. Each cut was weighed separately. The breast, drumstick and thigh cuts of the right side were skinned and deboned. The meet and bone were weighed separately. The meat was frozen and stored for further analysis.

The taste panel:

Frozen deboned breast, drumstick and thigh cuts of right side were thawed at 5-7°C before cooking for sensory evaluation. The meat was trapped in aluminum foil, placed in roast pan and cooked at 176.7ºC/hours in conventional preheated electrical oven to about 80°C internal muscle temperature. The cooked meat was allowed to cool to room temperature in about 10 minutes. The samples were kept warm until served. Trained panelists were instructed to eat crackers drink water between samples testing to clear the plate and pause for 20 seconds between all samples evaluated; following recommended procedure (Hawrysh *et al*., 1980). The sensory panel evaluated the chops for tenderness, flavour, colour and juiciness using an eight-point scale (Appendix).

Chemical methods:

According to A.O.A.C. [1988] the sorghum, maize grains and meat samples were proximately analysed.

3.6. Statistical analysis:

Data were statistically analyzed by the General Linear Model (GLM) of SAS (1990) using the replicated means of all parameters. Two ways analysis of variance was used. The model included xylam 500 enzyme and energy sources, (Maize and Sorghum), and two ways of interactions.

Table 1. The ingredients percent composition of experimental diets

Ingredient	Diets			
	A	B	C	D
Sorghum {Feterita}	65.6	65.6	-	-
Yellow maize	-	-	59	59
Groundnut cake	26.65	26.65	32.55	32.55
Vegetable oil	0.3	0.3	1	1
Concentrate *	5	5	5	5
Dicalcium phosphate	1	1	1	1
Limes stone	1	1	1	1
Salt	0.25	0.25	0.25	0.25
Lysine	0.1	0.1	0.1	0.1
Methionine	0.1	0.1	0.1	0.1
Total	100	100	100	100
Feed additive xylam 500 enzyme kg/ton	-	0.5	-	0.5

* crude protein 40%; crude fat 3.90%; crude fiber 1.44%; calcium 10%; available phosphorus 6.40%; energy 1950 K cal/Kg; methionine 3%. Methio + cystin 3.3%; lysine 10-12%; crude minerals 39.30%. sodium 2.77%; linoleic acid 0.24%; Nacl 6%. Vitamins: vit, A 200.000 I.U/Kg; D3 70.000 I.U/Kg; Experiment 400 mg/Kg; K3 30mg/Kg; B1 50mg/Kg; B2 150mg/Kg; B6 50mg/Kg; B12 180 mcg/Kg.

D Pantothenic acid 155 mg/Kg; Niacine 440 mg/Kg; folic acid 8 mg/Kg; choline chloride 5.800 mg/Kg; Antioxydant (BHT) 1000 mg/Kg.

Trace Elements; Manganise 1600 mg/Kg; zinc 1600 mg/Kg; Iron 580 mg/Kg; copper 450 mg/Kg; Iodine 55 mg/Kg; selenium 8 mg/Kg; Cobalt 9 mg/Kg; Molbden 20 mg/Kg.

Table 2. Calculated chemical analysis of experimental diets

Components %	**Diets**			
	A	**B**	**C**	**D**
Dry matte	95.10	95.10	95.90	95.90
Crude protein	22.75	22.75	22.75	22.75
Crude fibre	4.92	4.92	4.94	4.94
Ether extract	4.09	4.09	6.91	6.91
Ash	4.02	4.02	4.48	4.48
Nitrogen free extract	59.32	59.32	56.82	56.82
ME Kcal/kg	3100	3100	3100	3100

CHAPTER FOUR

RESULTS

Response of broiler chicks to dietary microbial xylanase and source of energy

4.1. Chemical composition of sorghum (Feterita) and Yellow maize:

The crude protein content of yellow maize was significantly ($P<0.05$) lower than that of maize. Sorghum grain had significantly ($P<0.05$) higher crude fiber and lower ether extract values compared to yellow maize, while the two cereals were almost similar in the dry matter, ash, nitrogen free extract and metabolizable energy values (**Table 3**).

4.2. Performance:

The effect of microbial and energy sources on the performance of broiler is shown in Table **(4)**. Initially all group starter at similar body weight (18٠ gm}.

The result indicated that the addition of xylanase enzyme to the broiler diet had no significant effect on the weight gain. However, the use of dietary microbial enzyme increased the body weight gain.

The result showed that the energy source had no significant effect on body weight gain, but the chicks fed on the diet containing maize gained more weight compared to those fed on sorghum grain.

The feed intake was not affected significantly by the addition of microbial xylanase enzyme in the diets. However, the chicks fed on diet containing microbial enzyme consumed more feed than control group.

The source of energy had no significant effect on feed intake, but the chicks fed on diet containing maize consumed more feed than those fed sorghum grain.

The results showed that the enzyme supplementation had no significant(P<0.05) effect on feed conversion ratio (FCR) and all values were closely similar in all treatment groups.

The FCR values were not affected significantly by the source of energy and all values were similar in treatment groups.

No mortality was recorded during the experimental period in all treatment groups.

Table 3. Determined chemical composition of sorghum (Feterita) and Yellow maize

Items	Sorghum {Feterita}	Yellow Maize	SE ±
Dry matter %	95.5[a]	95.3[a]	0.07
Crude protein %	13.70[a]	11.14[b]	0.06
Ether extract %	2.21[a]	5.43[b]	0.02
Crude fiber %	3.44[a]	2.92[b]	0.08
Ash %	2.33[a]	2.50[a]	0.32
Nitrogen free extract %	73.86[a]	74.14[a]	0.08
** Metabolizable energy {Kcal/kg}	3411[a]	3423[a]	0.82

* Means on the same row with the same superscripts are significant (P>0.05).

** Metabolizable energy was calculated according to the equation of Lodhi, *et al.*, (1976).

Table 4. The effect of dietary microbial xylanase and energy sources on the performance of broiler during (1-7 weeks).

	Treatment							
Diets	**Enzyme**	**Source of energy**	**Initial body weight**	**Live body weight**	**Weight gains**	**Feed intake**	**F.C.R**	**Mort. %**
A	Without	Sorghum	180	2014.4^{a}	1834.4^{a}	3675.8^{a}	2.00^{a}	0.0
B	Within	Sorghum	180	2057.6^{a}	1936.2^{a}	3798.4^{a}	2.02^{a}	0.0
C	Without	Maize	180	2120.6^{a}	1944.6^{a}	3718.2^{a}	1.92^{a}	0.0
D	Within	Maize	180	2168.2^{a}	1986.2^{a}	3808.0^{a}	1.92^{a}	0.0
SE ±				65.183	59.020	99.537	0.038	0.0
Main effects:								
Enzyme		M without	180	2067.5	1891.2^{a}	3697.^{a}	1.953	0.0
		within	180	2112.9	1961.2^{a}	3803.2^{a}	1.970	0.0
SE ±					41.733	70.384	0.027	0.0
Source of energy		Sorghum	180	2036	1887^{a}	3737.1^{a}	1.98^{a}	0.0
		Maize	180	2144.4	1965^{a}	3763.1^{a}	1.913^{a}	0.0
SE ±					41.733	70.384	0.027	0.0

Means with columns do not differ significantly (P>0.05).
SE ± = Standard error.
A = Sorghum without enzyme.

B = Sorghum with enzyme.

C = Maize without enzyme.

D = Maize with enzyme.

As seen in Table **5**, the interaction between the dietary microbial xylanase and source of energy was not statistically significant on weight gain, feed intake and feed conversion ratio.

4.3. Carcass and Measurements:

4.3.1. Carcass dressing and non- carcass yield:

The effect of dietary microbial xylanase and energy sources on the carcass dressing and giblet (gizzard, heart and liver) were presented in Table **5**. The results revealed no significant differences between the different experimental groups in all giblets parts.

4.3.2. Commercial cuts:

The results of Table **6** indicated that the selected commercial cuts (breast, thigh and drumstick) percentage of broiler chicks were not affected significantly by either microbial xylanase enzyme or energy sources.

4.3.3. Meat expressed from total weight of commercial cuts:

The values of meat expressed as percentage from total weight of commercial cuts selected are shown in Table **7.** Table **7** showed that neither dietary microbial xylanase enzyme nor source of energy had significant effect on the values of meat expressed as percentage from total weight of selected commercial cut of the broilers.

Table 5. The effect of dietary microbial xylanase and energy sources on the carcass dressing and giblet (gizzard – heart and liver) percentage of broiler chicks.

Diet	**Treatment**		**Dressing**	**Liver**	**Gizzard**	**Heart**
A	Without	Sorghum	70.00[a]	2.438[a]	2.302[a]	0.572[a]
B	Within	Sorghum	70.120[a]	2.408[a]	2.338[a]	1.578[a]
C	Without	Maize	69.650[a]	2.386[a]	2.296[a]	1.776[a]
D	Within	Maize	70.078[a]	1.934[a]	2.168[a]	0.966[a]
SE ±			1.357	0.149	0.188	0.250
Main effects						
Enzyme	Without		69.825[a]	2.412[a]	2.299[a]	1.174[a]
	Within		70.099[a]	2.171[a]	2.253[a]	1.272[a]
SE ±			0.960	0.105	0.133	0.250
Source of energy						
		Sorghum	70.060[a]	2.423[a]	2.320[a]	1.075[a]
		Maize	69.864[a]	2.160[a]	2.232[a]	1.371[a]
SE ±			0.960	0.105	0.133	0.177

Means with columns do not differ significantly (P>0.05).
SE ± = Standard error.
A = Sorghum without enzyme.
B = Sorghum with enzyme.
C = Maize without enzyme.
D = Maize with enzyme.

Table 6. The effect of dietary microbial xylanase enzyme and energy sources on the percent value of separable meat in commercial cuts of broiler chicks.

Diet	Treatment		Drumstick meat	Thigh meat	Breast meat
A	Without	Sorghum	77.43[a]	80.32[a]	79.84[a]
B	Within	Sorghum	77.35[a]	80.26[a]	79.64[a]
C	Without	Maize	77.36[a]	80.28[a]	79.63[a]
D	Within	Maize	75.35[a]	80.22[a]	79.68[a]
SE ±			3.26	1.28	1.62
Main effects					
Enzyme	Without		77.49[a]	80.30[a]	79.20[a]
	Within		70.40[a]	80.20[a]	79.30[a]
SE ±			2.30	0.90	1.14
Source of energy					
		Sorghum	77.30[a]	80.20[a]	79.20[a]
		Maize	76.30[a]	80.20[a]	79.30[a]
SE ±			2.30	0.90	1.14

Means with columns do not differ significantly (P>0.05).
SE ± = Standard error.

A = Sorghum without enzyme.

B = Sorghum with enzyme.

C = Maize without enzyme.

D = Maize with enzyme.

Table 7. The effect of dietary xylanase enzyme and source energy as percentage of carcass commercial cuts (breast, drumstick, thigh).

Diet	Treatment		Drumstick	Thigh	Breast
A	Without	Sorghum	16.35	19.14	23.38
B	Within	Sorghum	16.38	19.25	25.40
C	Without	Maize	16.39	18.92	23.51
D	Within	Maize	16.46	19.19	22.91
SE ±			0.40	0.69	3.44
Main effects					
Enzyme	Without		16.37	19.03	23.44
	Within		16.42	19.22	24.15
SE ±			0.28	0.49	2.43
Source of energy					
		Sorghum	16.36	19.19	24.39
		Maize	16.42	19.05	23.21
SE ±			0.28	0.49	2.43

Mean with columns do not differ significantly (P>0.05).

SE ± = Standard error.

NS = Not significantly difference (P>0.05).

A = Sorghum without enzyme.

B = Sorghum with enzyme.

C = Maize without enzyme.

D = Maize with enzyme.

4.4. Meat Quality Parameters:

4.4.1.Meat Chemical Composition {Objective Meat Parameters}:

The effect of dietary microbial xylanase and energy sources of the chemical composition were presented in Table **(8).** The statistical analysis showed that no significant ($P>0.05$) effect on {moisture, crude protein, ash, ether extract} and all values were closely similar in all treatment groups.

4.4.2.Panel Taste {Subjective Meat Attributes}:

Treatment effect on sensory values showed no significant differences between tested groups. Mean values of all sensory attributes colour, tenderness, flavour and juiciness are closely similar as shown in Table (**9**).

4.4.3. Economic appraisal:

Total cost, return and margins were explained in Table **(10)** calculations for total cost, total returned and profits showed that the supplementary of dietary microbial xylanase to the diet caused more net profit/kg in group B (10.43) compared to group A (9.79) and in group D the net profit/kg was (14.17) compared to group C (13.71).

Table 8. Effect of dietary microbial xylanase enzyme and energy sources on Meat Chemical composition of broiler chicks

Diet	Treatment		Moisture	Crude Protein	Ether Extract	Ash
A	Without	Sorghum	70.86	١٩.٣٠	٤.٦٣	١.٠٨
B	Within	Sorghum	٧٠.٨٨	19.31	4.64	1.02
C	Without	Maize	٧٠.٨٥	١٩.٣٢	4.60	1.02
D	Within	Maize	٧٠.٨٧	١٩.٣١	٤.٦٢	1.04
SE ±			0.88	0.95	0.58	0.06
Main effects						
Enzyme	Without		70.85	19.30	4.61	1.05
	Within		70.87	19.30	4.63	1.03
SE ±			0.62	0.67	0.41	0.04
Source of energy						
		Sorghum	70.87	19.30	4.63	1.05
		Maize	70.86	19.31	4.60	1.03
SE ±			0.62	0.67	0.41	0.43

Mean with columns do not differ significantly (P>0.05).

SE ± = Standard error.

A = Sorghum without enzyme.

B = Sorghum with enzyme.

C = Maize without enzyme.

D = Maize with enzyme.

Table 9. The effect of dietary microbial xylanase enzyme and energy sources on Subjective scores of commercial cuts of broiler meat.

Diet	Treatment		Tenderness	Flavor	Colour	Juiciness
A	Without	Sorghum	4.61	٦.٠٣	٦.١٠	٤.٦٣
B	Within	Sorghum	5.69	٥.٩٣	٦.٠٥	٥.٧٠
C	Without	Maize	5.65	٦.٠٧	٦.١٠	٥.٦٧
D	Within	Maize	5.59	٦.٠٠	٦.١٣	٥.٦٠
SE ±			0.34	0.33	0.26	0.35
Main effects						
Enzyme	Without		5.13	6.05	6.10	5.15
	Within		5.64	5.96	6.10	5.65
SE ±			0.25	0.23	0.18	0.25
Source of energy						
		Sorghum	5.15	5.90	6.07	5.16
		Maize	5.62	6.03	6.13	5.63
SE ±			0.25	0.23	0.18	0.25

Mean with columns do not differ significantly (P>0.05).

SE ± = Standard error.

A = Sorghum without enzyme.

B = Sorghum with enzyme.

C = Maize without enzyme.

D = Maize with enzyme.

Table 10. Total cost calculated according to (2012) a current (2012) price of meat (SDG) kg.

Items	Chick purchase	Total feed cost	Management	Total cost production	Revenue	Live weight	Dressing percentage	Average weight	Total revenue	Profit	Total revenue Total cost	Total profit
A	4.5	16.14	400	22.64	-	2014	70.00	1.41	32.43	-	32.43 22.64	9.79
B	4.5	15.20	400	21.70	-	2057	70.12	1.44	32.12	-	32.12 21.70	10.43
C	4.5	12.60	400	10.10	-	2120	69.65	1.47	32.81	-	32.81 19.10	13.71
D	4.5	13.50	400	20.00	-	2168	70.07	1.51	34.73	-	34.73 20.00	14.73

CHAPTER FIVE

DISCUSSION

This study was conducted to compare the effect of feeding sorghum (Feterita) and Yellow Maize based diet with or without xylanase enzymes on performance and carcass characteristics of broiler chicks.

The results of the proximate composition of sorghum and yellow maize used in this study showed that the crude protein content of yellow maize was lower significantly ($P<0.05$) than sorghum, while the two cereals grains were similar in metabolizable energy. These results were similar to those studies Mohammed *et al*., (2013), Etuk *et al*., (2012) and Kriegshauser *et al*., (2006). The ether extract values of yellow maize was significantly ($P>0.05$) higher than yellow maize. These results are in line with the findings of Cowieson, (2005), Etuk *et al*., (2012) and Mohammed *et al*., (2013). The sorghum grain had significantly ($P<0.5$) higher crude fiber content compared to maize. These results are differs with the findings of Mohammed *et al*., (2013) who found that the crude fiber of yellow maize was higher than sorghum (Feterita). The results of this study showed similarities between the dry natter, ash and free nitrogen extract of maize and sorghum which confirms the reports of Travis *et al*., (2006), Torki and Frashamand (2007) Kwari *et al*., (2011) and Mohammed *et al*., (2013).

In this study there were no signs of disease observed and all experimental stock looked apparently healthy. The general behavior of the stock also was good. The ambient which temperature during the experimental period fell within the thermoneutral zone has extracted no heat stress on the experimental birds. No mortalities were recorded among the different treatment groups throughout the experimental periods; this may be due to good hygienic situation of the experiment. In this study all birds were kept in clean disinfected environment following all hygiene regulation programs. Torab, (2008) reported that no significant differences in mortality rate observed between broilers fed sorghum or yellow maize based diets and it was in the normal range. Mukkawi (2004), Bin-Baraik (2010) and El-Saeed (2013) stated that the addition of commercial xylam enzyme to the diet had no significant effect on the mortality rate in broilers. All these results were remarkably similar to the results of the current study.

Although birds which fed on yellow maize had greater weight gain than those fed sorghum based diet, the weigh gain did not show significant differences between the two dietary treatment groups in this study. This results are in agreement with the reports of Al Khair, (2000); Tulasi *et al*., (2004), Carmencita *et al*., (2006); Clement *et al*., (2010); Kwari *et al*., (2012) and Ibitoye *et al*., (2012), who found that the body weight gain of broilers was statistically similar in sorghum compared to maize based diets. These results are not in line with the findings of Torab, (2008) who found birds fed on yellow maize maintained significant high body weight to the sorghum fed chicks. In contrast, Mohammed *et al*., (2013) reported that sorghum significantly superior to yellow maize based diets in terms of live weight gain of broiler chicks. The addition of the enzymes to the diet had no significant effect on the body weight gain, even though the diet supplemental with enzyme improved the body weight gain in the percent study. These results agree with the findings of Nian *et al*., (2011) and Makkawi (2009). These results contradict with the reports of Amoni *et al*., [2011], Cowieson *et al*., [2006[b]], Wyatt *et al*., (1997) Neill and Liu (2011) and Selle *et al*., (2010) who found that addition of microbial xylanase individually or in combination with amylase and protease to the sorghum or maize based diet had a significant effect on the body weight gain of broilers. These researchers assumed that the exogenous carbohydrates and protease enzymes improve body weight through increase nutrient digestibility not only via a reduction digesta viscosity but also via a reduction in cell integrity,generation of fermentable disaccharides, low-molecular weight polysaccharides and oligosaccharides, improving protein solubility, decreasing endogenous losses and overcoming anti-nutritional factors.

The feed intake in the present study tended to be higher in the chicks fed on yellow maize based diet compared with sorghum group, but the differences were not statistically significant. This result is equally in harmony with the findings of Al Khair (2000); Tulasi *et al*., (2004); Reddy *et al*., (2005); Torab (2008); Clement *et al*., (2010) and Marshall *et al*., (2011). These results disagreed with those obtained by Mohaedain *et al*., (1986) who found that maize fed chick showed significantly higher feed intake compared with those fed sorghum based diets.

This result may be due to the tannin content of sorghum variety used because the high level of tannin reduced feed intake (Hassan *et al*., 2003, Makkar, 2003, Kim and Miller, 2005). In contrast, Mohammed *et al*., (2013) stated that the birds fed sorghum (Feterita) based diet consumed significantly more feeds than those fed yellow maize diets. Further addition of enzyme to the two energy sources used in this study did not have any significant effect on the feed intake, but the chicks received diets supplemented with enzymes tended to consume more feed than control. These results are in line with the findings of (Nian *et al*., 2011 and Makkawi 2009), but differs with those obtained by (Amoni *et al*., 2011; Neill and Liu 2011; Selle *et al*., 2010 and Wyatt *et al*., 1997) who found that incorporation of enzymatic complex (xylanase, amylase and protease) or only xylanasis activity increased significantly the feed intake of broiler chicks received either sorghum or maize based diets.

The results showed that feed conversion ratio (FCR) in this study was not significantly affected in broiler fed either sorghum or maize based diets. These results are in consistent with the findings of Kwari *et al*., (2012); Ibitoye *et al*., (2012); Mohammed *et al*., (2013); Clement *et al*., (2010) and Torab, (2008), but these results differ from that shown by Al Khair (2000) who observed that sorghum (Feterita) fed chicks obtained significantly best FCR than those fed on maize based diet, whereas Camencit *et al*., (2006) reported that the feed conversion efficiency of birds fed with maize was significantly higher than those fed sorghum based diets. However, there were non-significant differences in FCR between the two energy sources, as far as enzyme addition was concerned in this study. These results agreed with thosereported by Makkawi (2009). These results contradict with Zenella *et al*., (1999); Pack *et al*., (1997); Hajati *et al*., (2009); Neill and Liu (2011); Lee *et al*., (2010) who stated that the FCR was improved significantly with the addition of the microbial enzymes to broiler diets containing either sorghum or maize as based diets.

The similarities and disparities in the performance between broilers fed sorghum and those fed maize diets may be due to the nutritive values of sorghum and maize grains produced by farmers varies greatly because of differences in soil, climate, genotype, diseases and management practices in regards to harvesting, drying and storing (Maier, 1995, Leeson and Summers, 1976, Ebadi *et al*., 2005). On the other hand, the responsiveness of diet or an ingredient to exogenous enzymes is elusive and difficult to be accurately defined but it includes factors such as, substrate concentration and accessibility, inherent digestibility, nutrient interactions, type and amount of anti-nutrient, solubility in water, type, sources and concentration of enzyme used, age and disease status of animal. (Bao *et al*., 2013, Sreenivasaiah, 2006).

The results showed no significant differences in the percentages of carcass dressing and giblets (liver, heart and gizzard) between broiler fed sorghum and maize based diets. This result agrees with Kwari *et al*., (2011), Mohammed *et al*., (2013), Issa *et al*., (2007) and Tulasi *et al*., (2004). These results disagree with the findings of Adamu *et al*., (2012) who stated that replacing maize with yellow sorghum variety in broiler diet resulted in increased dressing percentage, which could be due to higher protein content of yellow sorghum compared to maize. Also Ibitoye *et al*., (2012) stated that the higher values of liver and heart of birds fed on white and red sorghum compared with maize based diet shows hypertrophy which could be as a result of tannin in the feed that produces toxicity causing inflammation and firable liver. The supplementation experimental diets with enzyme did not have any significant effect on carcass dressing and giblets percentages in this study. Similar results were obtained by Amoni *et al*., (2011); Kidd *et al*., (2001) and Hassan *et al*., (2011). These results contradict with the reports of Hajati *et al*., (2009) who found that addition of enzyme to maize – soybean based diets increased carcass dressing percentage significantly. Wang *et al*., (2005, and Alam *et al*., 2003) reported increased carcass yield by addition of enzymes in broiler diets attributable to higher fat deposition and also for breast meat yield.

The energy sources effect in the present study was not significant on commercial cuts {thigh, breast and drumstick} percentages and their percent of separable tissue. This similarities between maize and sorghum based diets for commercial cuts are in line with the reports of Kwari *et al*., (2001); Medigu *et al*., (2009); Issa *et al*., (2007) and Kwari *et al*., (2012). This result contradict with that of Torab, (2008) who found that broiler chicks fed on sorghum (Feterita) based diets recorded significantly higher percentages of thigh and drumstick compared to the yellow maize based diets. The results of this study indicated that the commercial cuts and their separable meat percentages were not affected significantly by dietary enzymes. Confirmation of these findings obtained by Lee *et al*., (2010), Makkawi, (2009) and Zanella *et al*., (1999).

The results of the present study showed that neither sources of energy nor dietary enzymes had significant effect on broiler meat chemical composition (moisture, fat, protein and ash). These results were confirmed by the subjective meat quality values in broiler (tenderness, flavour, colour and juiciness). These results were in agreement with those obtained by Mukkawi (2009) who found that the addition of xylanase enzyme did not have any significant influence on either objective or subjective meat quality attributes of broilers fed sorghum based diet.

Economics of production analysis in terms of income over feed, management and chick cost indicated that, the higher income drived was on maize with or without enzyme supplementation compared to the sorghum based diets. This suggests that replacement of sorghum by maize in broilers diet would be economical and also cost effective. This may be due to its lower prices in some parts of the country (North of Sudan). On the other hand the competition between human and poultry industry in sorghum which is a stable food for human in the Sudan Leads to arise in its prices. Similar results were obtained by Mohammed *et al*., (2013). Adding commercial microbial xylam enzyme to the sorghum or maize based diets resulted in economic benefit, but the maize with enzyme is more profitable. These results are in line with the findings of Amoni *et al*., (2011), who reported that addition of xylam enzyme to maize based diets decreased the relative cost of broiler feeds and enhanced economic efficiency.

Conclusion and Recommendations

Conclusion:

- The productive performance of broilers was statistically similar in maize compared to sorghum based diets, but economically the maize diet was more efficient due to its low prices in some parts of country.
- The incorporation of commercial xylam enzyme in the broiler receiving maize or sorghum improved numerically the performance and resulted in economic benefits.
- Using maize or sorghum with and without enzyme in the diets made no changes in carcass yield and meat quality of broilers.

Recommendations:

 # Practical Implications:

- Based on the results of this study, the replacement of sorghum by maize in broiler diets is recommended to reduce the feed cost and increase the net profit of broiler production in the Sudan.
- The addition of commercial xylam enzyme to sorghum or maize based diets for broilers is economically wise and is recommended, but the use of maize diet with enzymes is more profitable.
- Increase areas for maize cultivation to reduce its prices and to be more available for poultry feeding to maintain sustainable production.

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Suggestions for future research:

◊ More studies comparing different types of maize with each other and with sorghum in poultry diets to select the best one for production of meat and egg.

◊ More careful and detailed economical studies for use of maize and sorghum grains as source of energy in broiler rations need to be run.

◊ Based on the findings of present study, it may be worthwhile to be investigated further, whether or not higher kevels of dietary commercial xylam enzyme, above {½ kg/ton} with sorghum or maize diets could give more beneficial effects.

◊ Further experimentations are need for broilers to test the synergistic effects of dietary enzymatic complex to included xylanase, amylase, protease and phytase on anti-nutritional agents in sorghum and maize grains.

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Appendix 1. Weekly maximum and minimum experimental pen temperature during the period (29 July – 9 September 2012).

Weeks	Temperature °C	
	Max	Min
1	٣٤	١٨
2	٣٦	٢٣.٥
3	٣٥	٢٣
4	٣٥	٢٢.٧
5	٣٧.٢	٢٧.٢
6	٣٩	٢٣.٥
٧ Average	36	23

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Appendix 2. Nutrient composition of sorghum (%).

Components	**Sorghum [c] (Nigerian local)**	**Sorghum [b] (Indian local)**	**Sorghum [d] (Brown cool coloured)**	**Sorghum [a](ICSV112)**
Dry matter	93.31	92.50	88.94	-
Organic matter	93.06	-	-	-
Crude protein	10.48	9.50	14.89	8.9
Ether extract	2.97	2.50	3.30	3.7
Crude fiber	2.01	2.70	3.01	1.2
Ash	6.91	1.20	2.59	1.7
NFE (Starch + sugars)	61.24	76.60	65.16	73.50
Gross energy (Kcal/kg)				

Adapted from Olomu (1995)[a]; Subramanian and Metta (2000)[b]; Abubakar *et al*., (2006)[c]; Etuk and Ukaejiofa (2007)[d].

Appendix 3. Amino acid composition of sorghum (g/kg) fresh basis

Sorghum	
Dry matter	870
Nitrogen	14.1
Arginine	3.4
Cystine	1.6
Glycine	3.5
Histidine	1.9
Isoleucine	4.2
Leucine	11.8
Lysine	2.1
Methionine	1.6
Phenylalanine	4.2
Serine	3.9
Threonine	2.9
Tryptophan	1.0
Tyrosine	3.8
valine	5.3

Adapted from PRC (1981) and NRC (1984).

Appendix 4. Vitamin potency of sorghum (fresh basis)

Sorghum	
Vitamin A (i.u/kg)	0.7
Vitamin E (i.u/kg)	12.0
Thiamine (mg/kg)	4.0
Riboflavin (mg/kg)	1.1
Nicotinic acid (mg/kg)	41
Pantothenic acid (mg/kg)	12
Vitamin B6 (mg/kg)	3.2
Vitamin B12 (mg/kg)	-
Choline (mg/kg)	450

Adapt from Bolton and Blair (1977).

Appendix 5. Proximate of common maize grains products

Parameter		**Maize grain**[b]
Moisture	% of fw	7.23
Protein	% of dw	6-12.7
NDF	% of dw	8.3-10.8
ADF	% of dw	3.0-4.3
Fat	% of dw	3.1-5.8
Ash	% of dw	1.1-3.9

Source: BNF[a]; NRC, 1994, 1998, 2001; Ensminger *et al.*, 1990
[a]: Monsanto (1995), Monsanto (1996a), Monsanto (1996b), Monsanto (1997) Aventis (1999), Monsanto (1999) Dow Agrisciences (2000) and Monsanto (2000).
[b]: values taken from Table 2.

Appendix 6. Levels of minerals, amino acids and fatty acids in common Maize grains

Parameter		Maize grain[a]
Calcium	% of dw	0.003-0.15
Phosphorus	% of dw	0.23-0.75
Argenine	% of dw	0.22-0.64
Histidine	% of dw	0.26-0.37
Isoleucine	% of dw	0.22-0.71
Leucine	% of dw	0.79-2.41
Lysine	% of dw	0.05-0.55
Methionine	% of dw	0.10-0.46
Phenylalanine	% of dw	0.29-0.64
Threonine	% of dw	0.27-0.58
Tryptophan	% of dw	0.04-0.13
Valine	% of dw	0.48-0.59
Cysteine	% of dw	0.08-0.32
Glycine	% of dw	0.26-0.49
Palmitic 16:0	% of dw	0.29-0.79
Stearic 18:0	% of dw	0.04-0.17
Oleic 18:1	% of dw	0.70-1.39
Linoleic 18:2	% of dw	0.67-2.81
Linolenic 18:3	% of dw	0.03-0.10

Source: Monsanto, 1995; 1996, NRC, 1994,1998, 2001; Ensminger *et al,*.1990.
[a]: Values for Ca and P.

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Card used for judgment of subjective meat quality attributes

Sensory Evaluation Card

Evaluate these samples for colour, flavor, juiciness and tenderness. For each sample, use the appropriate scale to show your attitude by checking at the point that best describes your feeling about the sample. If you have any question please ask. Thanks for your cooperation.

Name:……………………………………. Date:………………..

Serial	Sample Code	Tenderness	Flavor	Colour	Juiciness
		8. Extremely tender 7. very tender 6. moderately tender 5. slightly 4. slightly tough 3. moderately tough 2. very tough 1. Extremely tough	8. Extremely intense 7. very intense 6. moderately 5. Slightly 4. slightly bland 3. moderately bland 2. very bland 1. Extremely bland	8. Extremely desirable 7. very desirable 6. moderately 5. Slightly 4. Slightly undesirable 3. moderately undesirable 2. very undesirable 1. Extremely undesirable	8. Extremely juicy 7. very juicy 6. moderately 5. Slightly 4. slightly dry 3. moderately 2. very dry 1. Extremely dry

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