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**A Review**

# Nutrient Composition and Feeding Value of Sorghum for Livestock and Poultry: a Review

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## Abstract

Sorghum, an indigenous cereal of Africa benefits from an ability to tolerate drought, soil toxicities and temperature extremes effectively than other cereals. In terms of the nutritive value, cost and availability, sorghum grain is probably the next alternative to maize in poultry feed. The CP content of sorghum is higher than that of maize but about equal to wheat. The energy value of sorghum is rated as high as 90 – 100% of maize depending on the livestock specie. The dried leaves and stems form useful roughage for cattle and horses while the well matured plant can be used as green fodder or silage. It is however, unsafe to feed the young green plant since they contain dhurrin, a cyanogenic glycoside which on hydrolysis yields hydrogen cyanide (HCN). Sorghum brewers' dried grains, sorghum dust and malted sorghum sprouts by products from the use of sorghum in beer production are utilised to varying degrees in livestock and poultry feeding. Nutrient digestibility of sorghum is influenced by the level of tannin concentration in the grain, low starch availability, differences in cultivars, resistance to digestive enzymes, species and age of animals. Generally, sorghum appears to be well suited as a substitute for maize in livestock and poultry feeds.

**Keywords:** Sorghum, Livestock, Poultry, Feed

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## Introduction

The poultry industry has suffered more than any other livestock industry as a result of inadequate supply and high cost of feed (Hill, 1989; Mtimuni, 1995; Leplaideur, 2004) and feed cost is expected to continue in the upward swing (Conolly, 2012). Cereal grains constitute the major sources of energy in poultry diets in the tropics (Oluyemi and Roberts, 2000). However, maize has remained the chief energy source in compounded diets and constitutes about 50% of poultry ration (Ajaja et al., 2002). Pressure on maize, wheat and recently cassava has been on the increase worldwide with emphasis being placed on export and other diversified use mostly in flour based foods and ethanol production as an alternative source of fuel (Doki, 2007; Thornton, 2007). According to Etuk (2008), these trends require serious diversification of energy feedstuff for poultry. The fact that feed alone accounts for 70 – 80% of the recurrent production input in intensive monogastric animal production makes the utilization of multiple feed ingredients expedient (Mtimuni, 1995; Marie-Agnés, 2004). Field observations in Nigeria revealed the inclusion of sorghum and possibly wheat in poultry and rabbit diets (Ojo et al., 2005a; Abubakar et al., 2006; Etuk and Ukaejiofo, 2007).

*Sorghum bicolor* (L) Moench is widely grown in the semi-arid and arid savannah regions of Nigeria. Maunder (2002) reported that sorghum is a traditional crop of much of Africa and Asia and an introduced and hybridized crop in the western hemisphere. It benefits from an ability to tolerate drought, soil toxicities and temperature extremes effectively than other cereals. In terms of the nutritive value, cost and availability, sorghum grain is the next alternative to maize in poultry feed (Subramanian and Metta, 2000). Several varieties of sorghum have been developed and introduced in Nigeria (IAR, 1999). However, the diversity of chemical composition and anti-nutritional factors, mainly tannin resulting in variability in digestibility from 35 – 60% or more have been reported (Becker, 1992). Varieties of sorghum, climatic and soil conditions, fertilizer types are listed among the factors responsible for the variations in chemical composition of sorghum (Aduku, 1993; Tacon, 1995; Ngoka, 1997; Etuk and Ukaejiofo, 2007; Etuk, 2008).

In view of the need to diversify sources of feedstuff in poultry rations, this article discusses the possible nutritional value of sorghum in livestock and poultry feeds considering the diversity of chemical compositions and cultivated varieties.

## Origin and distribution of sorghum

Sorghum is indigenous to Africa and accounts for 43% of all major food staples produced in sub-Saharan Africa (IFPRI, 1983). Maunder (2002) considered sorghum as a traditional crop in much of Africa and Asia and an introduced and hybridized crop in the Western hemisphere. Doggett (1965) reported that sorghum was domesticated in Ethiopia some 5,000 or more years ago from wild sorghum, *S. arundinaceum sensu lato* by descriptive selection. It is suggested that a people of Hamitic stock who migrated into Ethiopia through the Middle East or through Arabia may have domesticated the wild sorghum, which occurred as weed in their wheat fields (Purseglove, 1972). Doggett (1970) documented that cultivated sorghum and its attendant weed, *S. arundinaceum*, were taken from Ethiopia to West Africa at an early date across Sudan to Upper Niger River, where sorghum was grown in Neolithic time. Sorghum was taken from Ethiopia to East Africa, which was occupied by bushmanoid hunters and food gatherers by Cushites who may have occupied favourable sites on high ground and practiced a terraced agriculture. Sorghum was taken from East Africa to India probably during the first millennium B.C. and probably reached China along the silk route from India in the early Christian era (Purseglove, 1972). It then spread to Mediterranean countries from materials brought from India and Africa. Sorghum was taken from West Africa as guinea corn to the new world by slave traders and introduced in the United States of America (USA) about the middle of the ninth century. Cultivated sorghum of the present arose from the wild progenitor belonging to the sub specie *Vertilliflorum* (FAO, 1995). The greatest variation in the genus sorghum was observed in the region of the northeast quadrant of

Africa comprising Ethiopia, Sudan and East Africa (Doggett, 1988).

## Varieties of sorghum

Sorghum belongs to the tribe *Andropogonae* of the grass family, *Poaceae*. Sugar cane (*Saccharum officinarum*) is a member of this tribe and a close relative of sorghum. In 1753, Linnaeus described in his species platinum, three species of cultivated sorghum: *Holcus sorghum*, *Holcus saccaratus* and *Holcus tricolour*. In 1794, Moench distinguished the genus sorghum from the genus *Holcus* and in 1805, Person suggested the name *Sorghum bicolor (L)* Moench as the correct name for cultivated sorghum (FAO, 1995). *Sorghum bicolour (L) Moench* is known under a variety of names, great millet and guinea corn in West Africa, kaffir corn in South Africa, durra in Sudan, Mtama in East Africa, joha ala cholam in India and kaoliang in China. Grain sorghum grown primarily for food can be divided into milo, kafir, hegari, feterita and hybrids (Purseglove, 1972). Norman et al. (1995) divided cultivated sorghum into five groups namely *bicolor*, *guinea*, *caudatum*, *kafir* and *dura* (Table 1). Seven agronomic groups have also been described by Magness et al. (1971) *viz* kaffir sorghums originally from South Africa; milo sorghums originally from East Africa; feterita sorghums from Sudan; durra sorghum from the Mediterranean area, Near East and Middle East; sballu sorghum from India; koaliang sorghum grown mainly in China, Manchuria and Japan and the hegari sorghums also from Sudan.

**Table 1:** Sorghum varieties and area of dominance

| Varieties | Area of Dominance |
|---|---|
| Bicolor | African savannah, South East Asia |
| Guinea | West Africa Savannah, India, South East Asia |
| Caudatum | Tropical Africa |
| Kaffir | Africa, South of Equator |
| Durra | Near East and India |

Source: Harland and deWet (1972); Norman et al. 1995.

The most abundant variety of sorghum in Nigeria is *Sorghum guineense*; other varieties include *Sorghum durra*, *Sorghum caudatum* and *Sorghum margaritiferum* (Irvine, 1953; Busson, 1965). Several cultivars have, however, been developed through sustained breeding. Maunder (2002) reported that the single most important technology change in sorghum since the 1950's has been the development and use of hybrid seeds. Several improved varieties have been developed and released to farmers in Nigeria since the 1970's mainly by the Institute of Agricultural Research (IAR), Ahmadu Bello University, Zaria and the International Centre for Crop Research for Semi-Arid Tropics (ICRISAT), Kano centre. Some of these cultivars have been developed from the local varieties, namely Fara-fara, Farida, Kaura and from the ICRISAT lines of the Sudan zone. [IAR, 1999; National Centre for Genetic Resources and Biotechnology (NCGRB), 2004]. Among these are the ICSV 111 and ICSV 400 released by ICRISAT in 1996, SAMSORG series developed and released in the 1970's and 1980's; others are the NR series developed from the Sudan zone ICRISAT line (NCGRB, 2004), L-187, L-243 and L-333 and SK-5912, which have pale yellow to yellow grains and L-1499, which have white coloured grains (Ega et al., 1992).

## Sorghum production

In the past 50 years, the area planted with sorghum worldwide has increased by 60% and the yield by 233% (Maunder, 2002). Total annual production ranges from 40 – 45 million tonnes from approximately 40 million hectares making sorghum one of the most important cereals in terms of production (ICRISAT, 2000). Table 2 shows the most important producers of sorghum in the world.

Between 1992 – 1994, Africa produced 27% of the world's total sorghum and the annual growth rate of area planted with sorghum was 3.7%, production 2.9% and yields 0.8% between 1980 – 1977 (Maunder, 2002). This indicates the importance of the crop in Africa, including Nigeria. Currently, sorghum cultivation is being promoted as a cash crop and safety net for farmers in Zimbabwe's arid regions (Pedrick, 2012). In Nigeria, sorghum is widely grown in the semi-arid and savannah regions; peasants produce virtually all of it (Ega et al., 1992). In the 2004/2005 farming season a total of 247 hectares were cultivated in Zambia yielding about 170 – 300 tonnes of grain (Marie-Agnés, 2006). Recent yields in Nigeria indicated values of 2.5 tonnes/ha, 2.6 tonnes /ha and 1.5 tonnes/ha on ploughed, ridged and surface hoed tillage methods, respectively (Abimiku et al., 2002). This encouraging yield is not unconnected with the introduction of high yielding varieties of sorghum and continuous development of these high yielding varieties.

**Table 2:** Important producers of sorghum

| Countries | Volume of production (tonnes) | Area cultivated (ha) |
|---|---|---|
| United States | 17.0 million | 4.0 million |
| India | 11.0 million | 12.5 million |
| Nigeria | 6.0 million | 5.7 million |
| China | 5.5 million | 1.5 million |
| Mexico | 4.5 million | 1.3 million |
| Sudan | 3.0 million | 5.0 million |

Source: ICRISAT (2000)

## Nutrient composition of sorghum

The nutrient composition of sorghum has been well documented (Oyenuga, 1968; ARC, 1976; Bolton and Blair, 1977; Poultry Research Centre (PRC), 1981; NRC, 1984; Aduku, 1993; Tacon, 1995; and Aletor, 1999, Etuk, 2008). Whole grains of sorghum contain approximately 89 - 90% DM, 8.9 – 15% crude protein (CP), 2.8% ether extract (EE), 1.5 – 1.7% ash, 2.1 – 2.3% crude fibre (CF), and 71.7 – 72.3% nitrogen free extract (NFE) on as fed basis (Ensminger and Olentine, 1978). A summary of the nutrient composition of whole grain of sorghum and maize is presented in Tables 3, 4 and 5 while the nutrient composition of whole kernel and fractions of sorghum is presented in Table 6.

**Table 3:** Nutrient composition of maize and sorghum (%)

| Components | Maize[c] | Maize[a] | Maize[b] *(Decan 103)* | Sorghum[c] *(Nigerian local)* | Sorghum[b] *(Indian local)* | Sorghum[d] *(Brown coat coloured)* | Sorghum[b] *(ICSV 112)* |
|---|---|---|---|---|---|---|---|
| Dry matter | 90.10 | 91.80 | - | 93.31 | 92.50 | 88.94 | - |
| Organic matter | 90.53 | - | - | 93.06 | - | - | - |
| Crude protein | 9.65 | 8.8 | 9.8 | 10.48 | 9.50 | 14.89 | 8.9 |
| Ether extract (fat) | 3.98 | 4.10 | 5.2 | 2.97 | 2.50 | 3.30 | 3.7 |
| Crude fibre | 1.99 | 2.10 | 1.4 | 2.01 | 2.70 | 3.01 | 1.2 |
| Ash | 9.47 | 1.00 | 1.3 | 6.94 | 1.20 | 2.59 | 1.7 |
| NFE (Starch + sugars) | 73.46 | 75.80 | 73.10 | 61.24 | 76.60 | 65.16 | 73.50 |
| Gross Energy (Kcal/kg) | | | 4140 | | | | 4120 |

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

The CP content of sorghum is higher than that of maize but about equal to wheat. In terms of energy value, sorghum is rated as high as 90 – 100% of maize depending on the livestock specie. However, sorghum is lower than maize but higher than wheat in fat content (Magness et al., 1971; Atteh, 2002). Ensminger and Olentine (1978) reported metabolisable energy (ME) value of 13.96, 14.04 and 13.70 MJ/kg, respectively for all grains, kaffir and milo types of sorghum. Abubakar et al.

(2006) reported a slightly lower calculated value of 12.15 MJ/kg and 12.92 MJ/kg ME energy for unmalted and malted sorghum, respectively. Malting increases the protein, soluble sugars and lysine and reduces tannin content of sorghum (Barrett, and Larkin, 1974; Wu and Well, 1980; Kubiezek et al., 1984).

**Table 4:** Amino acid composition of sorghum and maize (g/kg) fresh basis

| | Dry matter | Nitrogen | Arginine | Cystine | Glycine | Histidine | Isoleucine | Leucine | Lysine | Methionine | Phenylalanine | Serine | Threonine | Tryptophan | Tyrosine | Valine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sorghum | 870 | 14.1 | 3.4 | 1.6 | 3.5 | 1.9 | 4.2 | 11.8 | 2.1 | 1.6 | 4.2 | 3.9 | 2.9 | 1.0 | 3.8 | 5.3 |
| Maize | 852 | 13.5 | 4.3 | 3.8 | 3.3 | 2.6 | 3.0 | 11.1 | 2.5 | 2.3 | 4.5 | 4.3 | 3.2 | 0.4 | 3.9 | 4.3 |

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

**Table 5:** Vitamin potency of sorghum and maize (fresh basis)

| | Vitamin A (i.u/kg) | Vitamin E (i.u/kg) | Thiamine (mg/kg) | Riboflavin (mg/kg) | Nicotinic acid (mg/kg) | Pantothenic acid (mg/kg) | Vitamin B6 (mg/kg) | Vitamin B12 (mg/kg) | Choline (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|
| Sorghum | 0.7 | 12.0 | 4.0 | 1.1 | 41 | 12 | 3.2 | - | 450 |
| Maize | 5.0 | 22 | 3.5 | 1.0 | 24 | 4 | 7.0 | - | 620 |

Adapt from Bolton and Blair (1977)

Sorghum contains low levels of lysine but high tryptophan content relative to maize (Purseglove, 1972; Olomu, 1995). McDonald et al. (2000) reported that both maize and sorghum have the main limiting indispensable amino acids, arginine, lysine, methionine, cystine and tryptophan. Xanthophylls and linoleic acids are much lower in sorghum than in maize and yellow endosperm with carotene and xanthophylls increases the nutritive value of sorghum (FAO, 1995; Olomu, 1995).

**Table 6:** Nutrient composition of whole kernel and fraction of sorghum

| Kernel fraction | % Kernel weight. | Protein (%) | Ash (%) | Oil (%) | Starch (%) | Niacin (mg/100g) | Riboflavin (mg/100g) | Pyridoxine (mg/100g) |
|---|---|---|---|---|---|---|---|---|
| Whole kernel | 100.00 | 12.30 | 1.67 | 3.60 | 73.80 | 4.50 | 0.13 | 0.47 |
| Endosperm | 82.30 | 12.30 | 0.37 | 0.60 | 82.50 | 4.40 | 0.09 | 0.04 |
| Germ | 9.80 | 18.90 | 10.40 | 28.10 | 13.40 | 8.10 | 0.39 | 0.72 |
| Bran | 7.90 | 6.90 | 2.00 | 4.90 | 34.60 | 4.40 | 0.40 | 0.44 |

Adapted from FAO (1995).

Protein, oil, niacin and pyridoxine content of sorghum are highest in the germ fraction and lowest in the bran while the endosperm contains the highest level of starch (Table 6). There is a marked variability in the mineral composition of the four primary varieties of sorghum in Nigeria. *Sorghum guineense* contains high level of phosphorus and manganese, *S. margaritiferum* contained higher levels of iron and zinc, *S. durra* contains higher levels of potassium while *S. caudatum* recorded moderate levels of all the minerals evaluated (Busson, 1965; Oyenuga, 1968).

Sorghum *per se* is known to be high in fibre and tannin (Tacon, 1995; Aletor, 1999). The young shoot and newly sprouted seeds also contain dhurrin (Olomu, 1995; D'Mello, 2000; Oduguwa and Fafiolu, 2004). Sorghum leaves are reported to have a haematinic property in ethno-veterinary treatment in combination with *Telfaria occidentalis* (Adedapo et al., 2002).

## Sorghum in livestock nutrition

It has been reported that 51% of sorghum crops is used to feed livestock while 49% is for human food and other uses (Maunder, 2002). Also, 48% of sorghum grain production is fed to livestock which according to Dowling et al. (2002) is often compared to maize [*Zea mays varidentata* (sturter) Bailey] for which it is a close substitute. Carter et al. (1989) reported that sorghum is used primarily as feed grain for livestock in USA and that the feed value of the grain is similar to maize. Smith (1995) agreed and indicated that sorghum compares well with other feed grains in total carbohydrate, indicating its suitability as a feed grain. Similarly, Purseglove (1972) reported that sorghum is a valuable feedstock; the smaller seeded varieties and bran afford excellent food for all classes of livestock. The whole grain sorghum has more protein than maize but is lower in vitamin A. The grain is palatable though intake sometimes limits productivity but the feeding value ranges from 90% to nearly equal to maize (Carter et al., 1989).

Sorghum is often grown for forage or silage. The dried leaves and stems form useful roughage for cattle and horses. The well matured plant can be used as green fodder or silage. It is, however, unsafe to feed the young green plant since they contain dhurrin, a cyanogenic glycoside which on hydrolysis yields hydrogen cyanide (HCN) (Oyenuga, 1968; Purseglove, 1972; Adamu and Alhassan, 1993). The kernel of sorghum is somewhat similar to maize though smaller in size. Whole sorghum grains can be given to sheep, pigs and even poultry but are usually ground for cattle (McDonald et al., 1987; Carter et al., 1989; Atteh, 2002). Brand et al. (1990) observed comparable live weight gain (799 g/day *vs.* 809 g/day), feed conversion ratio (FCR) (2.87 *vs.* 2.98) and feed intake (2.20 kg *vs.* 2.38 kg) between pigs fed low tannin sorghum and maize meal, respectively. Similar results were also obtained by Kemm et al. (1984) but with slightly depressed live weight and FCR for pigs fed high tannin sorghum. Intramuscular fat of pigs which is positively associated with tenderness according to Ramsey et al. (1987) was higher in maize-fed pigs than sorghum fed pigs. According to Maunder (2002), sorghum may well offer the best opportunity to satisfy the doubling of meat demand in the developing world by 2020, as food for the poor, and as an alternative to maize. This is perhaps in line with Conolly (2012) who opined that feed cost is expected to continue in the upward swing while broiler meat consumption increased by 43% between 1999 and 2009.

Abubakar et al. (2006) reported that rabbits fed diets containing malted sorghum recorded a significantly higher weight gain (25.72 g *vs.* 22.37 g) than those fed unmalted sorghum. The weight gain of rabbits fed unmalted sorghum was also higher than those fed maize-based diet (25.72 g *vs.* 23.00 g). Feed efficiency, feed cost and feed cost per kilogramme weight gain were also lower for rabbits fed sorghum based diets thus producing cost savings of ₦18.80 and ₦24.19 for rabbits fed unmalted and malted sorghum, respectively. Olorunnisomo et al. (2006) concluded that sorghum brewer's grains stimulated a better weight gain and FCR in WAD sheep than maize offal (46.9 g *vs.* 27.2 g) and (0.14 *vs.* 0.12), respectively in a low protein diet including a reduction in feed cost. However, when protein content was adequate, sorghum brewer's grain and maize offal had similar effect. Dada (1993) reported that sorghum dust replacing maize at 50% and 100% in diets for weaner pigs did not significantly affect performance in terms of weight gain, feed intake, FCR though maize diets performed slightly better. Feed cost per kilogramme weight gain was nevertheless lowest in diet where sorghum dust completely replaced maize and highest in all maize diet (₦6.35 *vs.* ₦11.66).

## Feeding value of sorghum in poultry diets

Considering the nutritive value, cost and availability, sorghum grain is the next alternative to maize in poultry feed (Maunder, 2002). A study by Subramanian and Metta (2000) indicated that sorghum grain is as ideal as maize for poultry. Similarly, Augusto et al. (1974) earlier reported that generally, sorghum can replace all the maize in poultry diets provided xanthophylls are added for skin and egg yolk pigmentation. Pro and Cuca (1968) also indicated that comparing two varieties of wheat with sorghum and maize shows that sorghum was effective in poultry diet, including turkey. Results with turkeys indicated that maize, wheat and sorghum may be used effectively in poultry diets when fed on the basis of their nutrient composition in properly balanced poultry feeds (Waldroup et al., 1967). Spiridon et al. (1979) also observed no depressive effect of sorghum on growth and feed efficiency even at 100% replacement of maize with sorghum in meat chickens; however, carcasses of birds fed most sorghum diets were lighter than the control. Smithhard (2002) reported poor performance of poultry fed high tannin sorghum - based diet even when supplemented with soybean. Cullison (1987) nevertheless, reported that sorghum can replace 50% of maize with no adverse effect on animal performance though weight gain was reduced by 10% or more with higher levels.

Although sorghum has been used in poultry feed, farmers in India are reported to be apprehensive regarding use of sorghum in poultry feed (Subramanian and Metta, 2000). Farmers have the notion that sorghum has tannin and has low energy compared to maize grain. Studies by Kumar et al. (2007) revealed that feeding reconstituted red sorghum-based diet with a tannin content of 16 g/kg to broiler chicken did not exert any appreciable influence on nutrient utilization, blood biochemicals, enzymes and gross pathological changes even at 100% replacement of maize. However, raw red sorghum-based diet with 23 g/kg tannin fed to broiler chickens caused higher immuno-responsiveness in comparison to their reconstituted counterpart. It is possible that the development of low tannin sorghum could raise its value to comparable level with maize in poultry diet.

Luis (1980) noted that sorghum was similar to millet in true metabolisable energy (TME) but lower than maize. Dry matter digestion and gross energy of sorghum was, however, higher than millet. When sorghum was compared to millet and maize on an equal weight or a protein equivalent basis in broiler diets with adequate protein (22.5%), there was no significant differences in body weight gain or feed efficiency. Improta and Kellems (2001) compared raw, polished and washed quinoa with wheat, sorghum and maize on low protein diet (13.28%) and observed that at 21 and 28 days of age broiler chicks fed sorghum had the highest survival rate (100% and 96.72% *vs.* 96.37 and 96.3%), respectively, for sorghum and maize. Weight gains at day 7, 14 and 21 days of age were also highest for sorghum diet (88 g, 139.9 g and 221.0 g *vs.* 63.1 g, 76.05 and 91.0 g) respectively, for sorghum and maize based diet). Feed intake followed the same trend (33.48 kg *vs.* 26.36 kg) for sorghum and maize, respectively).

Results obtained with white and yellow local variety of sorghum in India showed no adverse effect on egg production with one-third (15%), as well as, whole replacement of maize (Table 7). Broilers fed both local (white and yellow) and improved (ICRISAT developed ICSV 112) varieties at 45% replacement level for maize recorded comparable performance in all parameters measured (Table 8) (Subramanian and Metta, 2000). This report agrees with earlier observation on the use of sorghum for layers and broilers (Thakur et al., 1984; Asha Rajam et al., 1986). However, Rama Rao et al. (1995) and Thakur et al. (1984) suggested that sorghum can replace maize from 50% to 74% only.

Blaha et al. (1984) working with 441 male broilers reported that sorghum (*Var. technicum*) could be used successfully as the only cereal components of diet for broilers. They observed that chicken given diet with sorghum had higher weight gains than those given diet with maize. However, FCR ratio was better with maize, whereas health of chicks and sensory characteristics of meat were not affected in chickens fed sorghum except for the pale skin, legs and beak. Edache et al. (2005) reported highest total weight gain (140.43 g), best feed/gain ratio (3.14) and lowest feed cost per kilogramme weight gain at 15% dietary level of sorghum replacing about 35.7% maize in quail diet. Quails fed 42% dietary level (100% maize replacement) of sorghum according to them recorded the highest feed cost per kilogramme weight gain (₦134.81), lowest feed cost per kilogramme (₦31.18) and poorest feed/gain ratio (4.84). Nevertheless, weight gain was not depressed.

**Table 7:** Performance of layers fed different varieties and dietary levels of sorghum

| Feed/ | Layers | |
|---|---|---|
| Variety | Feed intake (g/day) | Egg production (%) |
| 45% maize (composed) | 117 | 95 |
| 15% WS + 30% maize (D) | 118 | 94 |
| 45% White sorghum | 116 | 94 |
| 15%YS + 30% maize (D) | 118 | 96 |
| 45% Yellow sorghum | 116 | 94 |
| Maize (Deccan 103) | 102 | 83 |
| Sorghum ICSV 112 | 99 | 82 |
| ICSV 112 + maize (1:1) | 102 | 84 |

YS = Yellow sorghum (local); WS = White sorghum (local); C = Maize commercial; D = Maize (Deccan 103)
Source: Subramanian and Metta (2000).

**Table 8**: Performance of broilers fed different varieties and dietary levels of sorghum

| Feed Composition | Feed intake (g/bird/day) | Weight gain (kg/bird) | Feed conversion ratio |
|---|---|---|---|
| Maize (C) (60%) | 42.4 | 1.12 | 3.30 |
| 15% WS + 45% maize (C) | 42.3 | 1.18 | 3.22 |
| 45% WS + 15% maize (C) | 41.2 | 1.15 | 3.35 |
| 15% YS + 45% maize (C) | 39.5 | 1.11 | 3.87 |
| 45% YS + 15% maize | 44.4 | 1.24 | 3.18 |
| Maize (Deccan 103) | - | 1.63 | - |
| Sorghum (ICSV 112) | - | 1.53 | - |
| ICSV 112 + maize (Deccan 103) 1:1 | - | 1.62 | - |

YS = Yellow sorghum (local); WS = White sorghum (local); C = Commercial maize
Adapted from Subramanian and Metta (2000)

Sorghum by-products are either utilised or tested for use in poultry diets. Sorghum based brewers' dried grains have found effective use in poultry diet (Atteh and Fasikun, 1993 and Uchegbu et al., 2004). Finisher broilers according to Atteh and Fasikun (1993) could tolerate dietary sorghum based brewers by-products without detrimental effect on performance and nutrient retention, optimum daily weight gain and feed/gain ratio were obtained at 20% dietary level. Sorghum dust, an extracted residue from the use of sorghum in beer production according to Ajaja et al. (2002) led to a decrease in weight gain of birds, maize and sorghum dust however, supported similar haematological development in chicks. Agbede et al. (2002) reported that 25% sorghum dust for broiler chicks with 100 g/kg Roxazyne G enzyme supplementation did not show any deleterious effect on growth, blood, serum and liver components. They recommended 1:1 combination of maize and sorghum dust. This recommendation agrees with the report of Dada (1993) that showed a significant decline in performance of starter broilers beyond 50% replacement of maize with sorghum dust. However, finisher broilers showed significant depression in weight gain even at 50% replacement of maize with sorghum dust; dressed weight and dressing percentage were nevertheless not significantly affected even at 100% replacement of maize with sorghum dust. Malted sorghum sprouts, another by-product of sorghum from the brewery, have been shown to significantly reduce percentage hen-day production at 15 and 30% dietary levels (Fafiolu et al., 2004). Started chicks fed malted sorghum sprouts diet at 15% and 30% dietary levels recorded lower weight gains and feed intake probably due to the bitter taste of the sprouts (Oduguwa and Fafiolu, 2004).

## Nutritional value of sorghum in turkeys diets

Feeding of sorghum to turkey has been investigated by Pro and Cuca (1968), Waldroup et al. (1967) and Dosay (1993). When sorghum (commercial milo strain) was compared to maize and millet Dstrain on an equal weight or protein equivalent basis in starting turkey diets containing an optimal protein level (28%) and with adequate supplemented methionine, there were no significant difference in body weight gain and feed efficiency among the grains. Four sorghum grain types (commercial milo, AR 64, 9040 and CK 60) were compared to maize and millet C and D strains showed no difference in performance of starting turkey (Luis, 1980). Etuk and Ukaejiofo (2007) reporting on brown coat coloured sorghum which contained 0.42% tannin observed a significantly higher body weight gain and feed intake when sorghum and maize were offered on 1:1 ratio to unsexed starter local turkeys (0 – 6 weeks) (Table 9). Feed cost (₦/kg) was lowest for maize based-diet and highest for diets containing 100% replacement of maize with sorghum which surprisingly recorded the best FCR. Unsexed grower local turkeys (6 – 12 weeks) fed the same strain of sorghum recorded the highest weight gain (1393.75 g) and feed intake (5661.88 g) at 25% sorghum replacement of maize. Grower turkeys (6 - 12 weeks) on 0% sorghum recorded the best FCR. However, feed cost per kilogramme decreased with increasing level of sorghum in the diet. Feed cost per kilogramme weight gain was also lowest among grower turkeys fed 100% replacement of maize with sorghum (Mgbenu, 2005). Among unsexed finisher local turkeys (12 – 18 weeks) fed the same brown coat coloured local sorghum, highest weight gain (1570 g), lowest feed cost per kilogramme and feed cost per kilogramme weight gain were recorded for turkeys fed diet containing 100% replacement of maize with sorghum (Obi, 2005). Ojewola et al. (2002) reported that the quantity of feed consumed by the local turkey poults is inversely related to the concentration of dietary energy.

**Table 9:** Performance of local turkeys fed brown coloured local sorghum grain

| Dietary combinations | | Weight gain (g) | Feed conversion ratio | Feed intake (g) | Feed cost/kg weight gain (₦) |
|---|---|---|---|---|---|
| 100% maize | a | 506.0 | 2.57 | 1299.60 | 149.39 |
| | b | 1325.00 | 3.91 | 5179.36 | 246.41 |
| | c | 1681.00 | 4.35 | 7320.00 | 267.91 |
| 25% sorghum + 75% maize | a | 586.15 | 1.93 | 1130.70 | 115.61 |
| | b | 1393.75 | 4.06 | 5661.88 | 251.99 |
| | c | 1470.00 | 4.86 | 7175.00 | 287.17 |
| 50% sorghum + 50% maize | a | 725.40 | 1.88 | 1330.00 | 115.90 |
| | b | 1089.55 | 4.81 | 5241.25 | 293.59 |
| | c | 1425.0 | 4.89 | 6979.00 | 282.83 |
| 75% sorghum + 25% maize | a | 455.60 | 2.04 | 928.60 | 129.35 |
| | b | 1168.75 | 4.43 | 5176.88 | 265.91 |
| | c | 1447.5 | 4.93 | 7140.00 | 278.84 |
| 100% sorghum | a | 628.15 | 1.78 | 1128.50 | 116.00 |
| | b | 1343.75 | 3.94 | 5300.00 | 232.84 |
| | c | 1570.00 | 4.65 | 7301.00 | 251.51 |

***Source:*** Etuk and Ukaejiofo (2007) Starter [a] (0 – 6 week)
Mgbenu (2005) Grower [b] (6 – 12 weeks)
Obi (2005) Finisher [c] (12 -18 weeks)

## Digestibility and energy value of sorghum grain and sorghum by-products

The digestibility of cereals varies tremendously based on genetic background. Becker (1992) reported that the digestibility of millet found in Niger could range from 35% to 60% among about 200 different varieties. In the opinion of Rooney and Pflugtelder (1986) among cereals, sorghum has the lowest starch digestibility due to the resistance to digestive enzymes of the hard peripheral endosperm layer. Similarly, a study with growing pigs showed that digestibility was highest for cassava, followed by maize, sorghum and barley (Pascual-Reas, 1997; Rowe et al., 1999). Cousins et al. (1981) noted that variations exist among sorghum cultivars, especially those low in tannin which appears to have the same digestibility as maize.

There are also large differences between animal species in their capacity to digest cereal starch. Ostrowski - Meissner (1984) and Farhat et al. (1998) reported that most energy values in poultry are based on leghorn rooster evaluations while specie differences have been observed. On the other hand, Dale and Fuller (1980) and Robbins and Firman (2006) reported that there is no difference between the ME values of cereals in chickens and turkeys including rooster. The digestibility of sorghum starch across the whole digestive tract of poultry is 99% compared with 87% for cattle (Rowe et al., 1999). Within specie, age differences also affect digestibility of feedstuff. This fact has long been recognised when comparisons were made of AME values of some feedstuff fed to young and old birds with AME values tending to increase with age (Johnson, 1987). However, Mandal et al. (2006) observed no significant difference in the AME values of white (low tannin), brown (medium tannin) and red (high tannin) sorghum varieties fed to cockerel (chickens), guinea fowl and quail. Significant variations also exist between grains in the digestibility of starch in the rumen of cattle with reported values of 92%, 65% and 62% respectively, for oats, maize and sorghum.

Dowling et al. (2002) reported that the overall total digestible nutrients in sorghum are roughly 95% of those in dry rolled yellow dent maize; this is due to lower starch availability because sorghum starch content varies and is bound in a thicker protein matrix (Table 10). The chemical nature of the starch, particularly amylose and amylopectin content, is yet another factor that affects its digestibility. The starch digestibility was reported to be higher in low amylase (waxy) sorghum than in normal sorghum, maize and pearl millet grains (Hibberd et al., 1982). The actual dietary energy content of any feedstuff therefore will depend on its chemical composition since all organic components have an energy yielding value (Hardy, 1991; Ega et al., 1992). Ranjhan (2001) suggested that chemical composition gives only the potential value of feed though the quantity of carbohydrate, fat and protein does help in measuring the usefulness of feed.

**Table 10:** Dry matter, organic matter and energy digestibility in pigs

| Nutrients | Digestibility (g) | | | |
|---|---|---|---|---|
| | **Cassava** | **Maize** | **Sorghum** | **Barley** |
| Dry matter | 87.1 | 86.5 | 86.0 | 80.40 |
| Organic matter | 91.2 | 89.9 | 89.2 | 84.30 |
| Energy | 88.7 | 87.8 | 86.4 | 81.90 |

Adapted from Pascual – Reas (1997).

Nutrient digestibility of sorghum is also influenced by the level of tannin concentration in the grain (Rostangno et al., 1973; Guillaume and Belec, 1977; Sibbald, 1977).

Mandal et al. (2006) reported a negative correlation between tannin concentration and $AME_N$. The $AME_N$ value of high tannin red sorghum was significantly lower than those of medium tannin brown sorghum and low tannin white sorghum (11.3 MJ/kg *vs.* 12.5 MJ/kg *vs.* 12.8 MJ/kg) ME. Enhanced activities of lipase due to dietary tannins have been reported (Griffiths and Moseley, 1980; Horigome et al., 1988). It is probable that tannins stimulate an increased pancreatic secretion of all digestive enzymes but have little affinity for lipase in the gut. Both enzyme inhibition and formation of complexes of dietary tannins with proteins and carbohydrate may cause reduction in digestibility (Kumar and D’Mello, 1995). However, the digestibility reducing effects of tannins are not uniform; the diversity of effects may arise in part due to the differences in chemical nature of tannins and in part due to physiological capabilities of animals to handle tannins (Kumar, 1992). It has, however, been reported that the nutritional value of sorghum with tannin content lower than 10 g/kg was similar to that of maize (Lucbert and Castaing, 1986). Sibbald (1977) also reported TME value of 13.82 and 16.62 MJ/kg ME for high and low tannin grain sorghum, respectively while Queiroz et al. (1978) found the nitrogen corrected metabolisable energy (MEn) value of 12.08 and 12.94 MJ/kg for high and low tannin grain sorghum, respectively.

Several methods have been developed to estimate the energy value of sorghum based on tannic acid concentration, proximate composition and crude fibre assay.

ME (kcal/kg) = 3062 + 887 x CF – 202.5 x $(CF)^2$ (Moir and Connor, 1977)

Another equation based on the tannin content of sorghum has been reported *viz*;

ME (kcal/kg) = 38.55 x DM – 394.59 x tannic acid (Janssen, 1989)

Metabolisable energy can also be estimated for diets containing sorghum based on proximate composition viz;

ME (kcal/kg) = (36.21x CP) + (85.44 x EE) + (37.26 x NFE) (Janssen, 1989)

ME (kcal/kg) = (35.0 x CP) + (81.8 x EE) + (35.5 x NFE) (Pauzenga, 1985)

Apparent and true metabolisable energy values for sorghum based brewer's by-product have been reported as 7.70 and 7.90 MJl/kg, respectively (Atteh and Fasikun, 1993). In their study with sorghum dust in replacement for maize in broiler chick diets, Ajaja et al. (2002) reported an increase in nitrogen retention with increasing level of sorghum dust (1.40 – 1.75 g/chick/day). Apparent nitrogen digestibility however, reduced with increasing level of sorghum dust from 77.5% - 73.6% and considering the attendant limiting amino acids hinder the nitrogen utilisation (Nwokolo et al., 1985). Similarly, Agbede et al. (2002) reported a progressive increase in nitrogen retention of broilers fed sorghum dust in replacement of maize up to 50%. However, they observed that supplementation of the diet with 200 mg/kg of Roxazyme G enzyme further significantly increased nitrogen retention and apparent nitrogen digestibility (Table 11). Twelve week old BUT stag 9 turkey strains fed whole wheat in replacement of 50% maize recorded a digestibility value of 61.0% DM, 83.7% CP, 76.1% CF, 80.59% EE, 68.24% ash, 48.98% NFE and AME of 8.06 MJ/kg. Digestibility values for all nutrients were significantly lower than that for maize-based diets except for ash retention where a significantly higher value (68.24% *vs.* 65.08%) was recorded (Ojo et al., 2005b).

**Table 11:** Nutrient utilisation of broiler chicks fed sorghum dust-based diets

| Parameters | Replacement levels of sorghum dust for maize (%) | | |
|---|---|---|---|
| | **0** | **25** | **50** |
| Nitrogen retention (g/chick/day) | 1.4 | 1.6 | 1.7 |
| Apparent Nitrogen digestibility (%) | 77.5 | 77.5 | 73.6 |
| Protein efficiency ratio | 2.4 | 1.8 | 1.7 |

Adapted from Agbede et al. (2002).

Studies with sorghum brewers' grain in sheep indicated a slightly improved digestibility of DM (75.84% *vs.* 74.26%), CP (71.80% *vs.* 70.38%) and Neutral Detergent Fibre (NDF) (77.90% 76.34%) over maize offal. However, energy digestibility was higher for sheep fed maize offal than sorghum brewers' grain (78.38 *vs.* 75.65%) (Olorunnisomo et al., 2006).

## Conclusion

In conclusion it is noteworthy that appropriate varieties of sorghum will facilitate a more profitable utilisation of sorghum in feeding livestock and poultry. A combination of sorghum and other energy sources, as well as, malting could also enhance the effective utilisation of sorghum in livestock and poultry feed by reducing the effect of tannins.

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