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Review of Nutritional Value of Sorghum for Chicken Feeding

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Abstract

Sorghum is an important cereal crop and plays a key role in animal feed and human. Although it is similar to maize in chemical composition sorghum has great drought tolerance and requires minimal fertilizers on marginal lands for cultivation, tolerate soil toxicities and temperature extremes effectively than other cereals. Sorghum contains some anti-nutritional factors especially tannin which inhibit the use of important nutrients like protein, energy and minerals (phosphorus, calcium, zinc and magnesium) in diets. Cereal grains like maize and sorghum constitute the major sources of energy in poultry diets. The major cost of production of egg and meat in commercial poultry production is feed. So to overcome this conflict we must find such alternative products by developing diets which allow locally available cereal ingredient like sorghum that can meet the energy requirement of the birds through reducing the tannin content of poultry feeds and using improved varieties of sorghum.

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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 (Leplaideur, 2004). Feed cost is expected to continue in the upward swing (Conolly, 2012). The major cost of production of egg and meat in commercial poultry production is feed (Gebeyew *et al.*, 2015 and Ravindran, 2014).

The energy level of the feed is the major factor influencing feed intake as birds will under normal circumstances eat to satisfy their energy needs. The ever-rising prices of feed ingredient remained to be the greatest single item determining the profit margins in poultry farming, especially in developing countries. The most appropriate strategy for this challenge is to develop diets which allow locally available cereal ingredient that can meet the energy requirement of the birds to be used. Such an approach would reduce feed costs as well as the dependency on imported and conventional feed materials. Cereal grains constitute the major sources of energy in poultry diets in the tropics (Etuk *et al.*, 2012).

The use of maize as the main energy source in poultry diets is subjected to competition between animals and humans (Atteh, 2002). The grain is increasingly being used to produce ethanol, and many areas in the world are not self-sufficient in grain production to meet human and animal needs.

As a result of its multiple uses and relatively higher moisture requirement for growth, use of maize in drier areas, most part of the country may be limited in the future. In comparison to maize, sorghum can be grown successfully on relatively poor soils and with lower moisture condition (Medugu *et al.*, 2010). It is abundant in most parts of Africa and Asia, and it is among the main cereal crops that are used as food and feed. The adaptive agronomic characteristics of sorghum make it suitable for cultivation in different environmental conditions. Sorghum varieties have been used for many years for poultry and human consumption, especially in Africa and Asia (Sedghi *et al.*, 2011). While some authors have reported anti-nutritional factors in sorghum grain that have adverse effects on the utilization of sorghum protein and metabolisable energy by poultry, such as tannins. In human beings, sorghum that is consumed as refined or whole grain has proved to have potential health benefits (Mabelebele and Iji, 2013).

Sorghum has great drought tolerance and requires minimal fertilizers on marginal lands for cultivation; tolerates oil toxicities and temperature extremes effectively than other cereals. Sorghum is next crop to maize in terms of cost, nutritive value and availability as poultry feeds (Subramanian and Metta, 2000). Thus sorghum is playing a critical role for food security in some semiarid areas of the country (Beta and others 2004; Dicko and Cramer *et al.*, 2011). Sorghum is a singularly viable food grain crop for many foods insecure people in sub-Saharan Africa because it is rather drought resistant among cereals and can withstand heat stress. Those parts of Africa, where sorghum is a significant arable crop are semi-arid and include the highlands of east Africa where bi-modal rainfall is intermittent. Sorghum is not only drought resistant but can also with stand periods of water-logging (Belton, 2004).

Sorghum is an important cereal crop and plays a key role in animal feed and human (Kaufman *et al*., 2013, Sedghi *et al.*, 2011). Although it is similar to maize in chemical composition, it has been associated with sub-optimal and inconsistent poultry performance (Ravindran, 2014), (Black *et al*., 2005; Bryden *et al.*, 2009,). Apart from food and feed uses, sorghum is also becoming an important ingredient for industrial applications. Sorghum is a versatile crop industrialized countries like USA, it is mainly grown for the production of animal feed (forage or grain), in the manufacture of ethanol and as bio energy crop for production of biomass, whereas in Africa and Asia sorghum is grown primarily for human consumption. Sorghum is a valuable crop also due to the numerous utilizations of each part of the plant within different agricultural systems. The whole plant is often used as forage, silage or hay, while the stems for building, weaving or firewood; stems of some varieties are also used as biomass for biogas production or processed for sugar and syrup. The seeds are used in the livestock sector, as feed for poultry, cattle and swine (Duplessis, 2014).

Literature review

Origin and Distribution of Sorghum

Sorghum is classified under the family Poaceae (grass family), tribe andropogoneae, species *S.bicolor*. It is the 5th most important cereal crop in the world, after wheat, maize, rice and barley (Beta *et al.,* 2004; Waniska *et al.*, 2004; FAO, 2012). It is the second major crop (after maize) across all agro-ecologies in Africa (Taylor, 2003). Domesticated in North Africa, possibly in the Nileor Ethiopian regions around 1000BC (Kimber, 2000).

Sorghum is cultivated in wide geographic areas in the Americas, Africa, Asia and the Pacific. It is the third important cereal (after rice and wheat) in India. It is the second major crop (after maize) across all agro ecologies in Africa. Sorghum is a major cereal crop in arid and semi-arid areas of the world. It is a staple crop of semiarid sub-Saharan Africa.

Sorghum is a major food and nutritional security crop to more than 100 million people in Eastern horn of Africa, owing to its resilience to drought and other production constraints (Gudu *et al.*, 2013). Sorghum is indigenous to Africa and accounts for 43% of all major food staples produced in sub Saharan Africa considered sorghum as a traditional crop in much of Africa and Asia and an introduced and hybridized crop in the Western hemisphere (Maunder, 2002).

Varieties of Sorghum

Sorghum belongs to the tribe andropogonae of the grass family, Poaceae. *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, johaala cholam in India and kaoliang in China. Cultivated sorghum divided into five groups namely bicolor, guinea, caudatum, kaffir and dura. 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; kaoliang sorghum grown mainly in China, Manchuria in Japan and the hegari sorghums also from Sudan (Gudu *et al.*, 2013).

New varieties of grain sorghum are an excellent source of protein and energy for broilers, egg layers, turkeys and waterfowl. Because sorghum is often grown in areas where water resources are limited, sorghum production requires fewer environmental resources. Thus, some users of grain sorghum consider it to have less environmental impact compared to grains requiring larger allotments of moisture and fertilizer. When competitively priced, grain sorghum can be used at up to 70% in a broiler and layer rations and 55% in turkey rations replacing all of the corn.

Nutrient Composition of Sorghum

Sorghum is self-pollinating summer plant belonging to the grass family of Poaceae. Sorghum grain is similar to maize with respect to chemical composition. The nutrient composition of sorghum has been well documented (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. The CP content of sorghum is higher than that of maize but 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 (Atteh, 2002). Sorghum contains low levels of lysine but high tryptophan content relative to maize. Sorghum proximate composition varies significantly due to genetics and environment. For example, high nitrogen fertilizer level increases grains protein content and decreases the amount of starch in the grain (Ralph *et al*., 2000).

Maize and sorghum have the main limiting indispensable amino acids, argentine, lysine, methionine, cystine and tryptophan. Sorghum has lower starch digestibility relative to other grains such as maize, rice, wheat and barley, although the degree of digestibility depends on the method of processing. The nutritional quality of sorghum proteins is diminished because they are more resistant to digestion and have low levels of essential amino acids such as lysine, tryptophan and threonine. In contrast, there are high levels of leucine (McDonald *et al.*, 2000). Sorghum is a source of B-complex vitamins such as thiamin, riboflavin, vitamin B6, biotin, and niacin that are diminished with grain refining processes including decortications. The mineral composition in sorghum is similar to millet, higher compared to maize but lower than wheat, and is predominantly composed of potassium and phosphorus Sorghum-based foods are a good source of both iron and zinc, although anti-nutrients such as phytates may diminish bioavailability (Hurrell *et al.*,).

Proteins

Protein is the second largest constituent of sorghum grain after starch (Taylor *et al.*, 2011). Sorghum proteins are classified as albumins, globulins, kafirins, cross-linked kafirins and glutelins (De Mesa *et al.*, 2010). Of these kafirins are the main protein, comprising 50-70% of total protein content (Belton *et al.*, 2006). The kafirins are prolamin storage proteins with limiting levels of some amino acids, in particular lysine, a disadvantage not unique among cereal grains. The kafirins differ in structure from the gliadin and glutenin storage proteins in wheat (Duodu *et al.*, 2003). Sorghum kafirins are poorly digested due to the formation of cross-linking especially when moist cooked, resulting in protease resistance. In vitro and animal studies have also shown that sorghum protein digestibility may be reduced by other protein, protein-phenol and carbohydrate-phenol complexes (Taylor and Taylor, 2002).

Starches

Sorghum grain is a good source of starch, containing approximately 71% of dry whole grain weight. The starch is encapsulated in granules that are located predominantly in the endosperm (storage tissue), though uniquely some are present in the pericarp (outer layer of grain). Sorghum starch is comprised of both amylose and amylopectin polysaccharides (branched polymers of glucose) with very low percentages of amylose present in the starch of waxy sorghum varieties compared to 24-33% in non-waxy sorghum starch (Taylor, 2010).

The lower starch digestibility reported for sorghum foods is not an intrinsic property of the sorghum starch granules themselves, but appears mainly to be a consequence of the interactions of the starch with the endosperm protein matrix, as well as with cell wall material and polyphenolic compounds, such as condensed tannins and flavonoids. These interactions inhibit carbohydrate-hydrolyzing enzymes, such as α-glucosidase and α-amylase, thereby lowering starch digestibility (Kim *et al.*, 2011*)*.

Phytochemicals

Most sorghum varieties, except white sorghums, have a high concentration of photochemical, Particularly

Phenolic compounds, which exhibit high antioxidant activity and are linked to health Benefits (Rooney *et al*., 2005). Infact, bran of some sorghum grain varieties reportedly has the highest antioxidant activity of all cereal crop fractions, even higher than many fruits and vegetables. Specifically, sorghum bran has up to two orders of magnitude higher antioxidant activity than oat bran and wheat cereal, and an order of magnitude higher than rice bran although the precise amount is highly dependent on the variety of sorghum (Awika, *et al*., 2004).

Nutritional and Feeding Value of Sorghum

The nutritional properties of sorghum are unique and variety dependent. Some varieties are rich in poly phenols, especially condensed tannins, as natural antioxidants (Dykes and Rooney, 2006). Other important nutrients of sorghum include dietary fiber, fat soluble and B vitamins, and minerals (Waniska *et al*., 2004). All nutritional properties make sorghum gain a spotlight for better production and utilization as human food and also an important feed for ruminants, pigs, and poultry. Various strategies have been suggested to improve feed values by increasing the digestibility of both protein and starch. Much of the sorghum utilization and product quality is to a large extent related to the quality of sorghum starch. Sorghum contains some anti-nutritional factors especially tannin which inhibit the use of important nutrients like protein, energy and minerals (phosphorus, calcium, zinc and magnesium) in diets (Liu *et al*., 2013).

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). Sorghum grain is as ideal as maize for poultry (Subramanian and Metta, 2000). Sorghum can replace all the maize in poultry diets provided xanthophylls are added for skin and egg yolk pigmentation and sorghum was effective in poultry diet, including turkey. 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. Carcasses of birds fed most sorghum diets were lighter. 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 biochemical‟s, 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 (Smithhard, 2002).

Sorghum by-products are either utilized or tested for use in poultry diets. Sorghum based brewers‟ dried grains have found effective use in poultry diet (Uchegbu, 2004). Finisher broilers 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 led to a decrease in weight gain of birds, maize and sorghum dust however, supported similar hematological development in chicks (Ajaja *et al*., 2002).

Nutritional value of sorghum in broilers diets

Broilers chickens play a significant role in the provision of animal protein required by man to meet his daily protein intake (Maidala and Istifanus, 2012). They have high growth rate, high feed conversion ratio, and also short generation interval (Atteh, 2003). The chicken meat is superior to that of other livestock species because it is associated with relatively lower calorie and sodium intake while containing high protein content than other sources of meat (Atteh, 2003). Poultry meat is nutritious, tender, juicy, tasty and generally appealing and accepted when processed (Omole *et al*., 2006).

The primary reason for including sorghum in diets for broiler chickens is for the provision of energy which is mainly derived from its starch component. However, the utilization of starch/energy in sorghum by poultry is suboptimal. Moreover, the digestibility of sorghum starch is inferior to that of maize on the basis of both *in vitro* (Giuberti *et al*., 2012) and *in vivo* (Liu *et al*., 2014a, Truong *et al*., 2016a).

Some sorghum varieties may contain condensed tannin, which has pronounced anti-nutritive properties. Grain sorghum contains high levels of phytate or phytic acid. In addition to minerals, phytate binds with protein through binary and ternary complexes and binds with starch directly or indirectly through starch granule-associated protein (Baldwin, 2001; Oatway *et al.,* 2001).

Due to this relationship, the enzymatic degradation of phytate increases availability of starch and protein in the sorghum. The use of phytase in poultry feed has also increased in response to increasing concerns over phosphorus (P) pollution in the environment. Quality of sorghum as a feed grain for chicken-meat production is somewhat better than the perceived value; nevertheless, the performance of broiler chickens offered sorghum-based diets is open to improvement. Two prime targets in this respect are reductions in concentrations of kafirin and non-tannin‟ phenolic compounds. kafirin, as a proportion of protein, is positively correlated with sorghum protein concentrations. Consequently, as protein contents of grain sorghum increase, kafirin concentrations will also increase in both relative and absolute terms. Therefore, it follows that „low-protein ‟sorghums are more likely to support better broiler performance than high-protein‟ varieties by virtue of lesser kafirin contents as demonstrated by Truong *et al.,* 2015a).

Nutritional value of sorghum in layer diets

When evaluating the potential of a feed ingredient for use in layer diets several factors need to be considered. These include not only rate of egg production and feed efficiency, but also egg weight, shell thickness, haugh units and yolk mottling. While many studies have reported the effects of high tannin sorghum on the growth and feed efficiency of chicks, relatively few studies have reported the effects of sorghum tannins on the performance of laying hens.

Many studies have, however, dealt with the effects of tannic acid supplementation. Supplementing layer diets with tannic acid has been reported to reduce feed consumption, egg production and egg weight and to cause an increase in the incidence and severity of yolk mottling.

Caution is required, however, when trying to equate the effects caused by tannic acid, hydrolysable tannin, with those of the condensed tannins of sorghum. It is not yet clear what level of sorghum tannin can be included in layer diets without adversely affecting egg production or feed efficiency. Many reports on the use of sorghum in layer diets gave no indication of tannin concentrations, making comparisons very difficult. Sorghum in poultry feed rations without affecting body weight and egg production performance of layer birds (Subramanian and Metta, 2000).

Quality traits of eggs produced by layer birds fed with sorghum based diets also comparable to that of maize-based diets except yolk color. Sorghum grain is higher than maize in protein content but lower in fat content.

The sorghum can replace all the maize in poultry diets provided xanthophylls are added for skin and egg yolk pigmentation. Egg production, egg weight, and yolk coloration were decreased when tannic acid was 2% of layers diets. In laying birds, tannins decreased the rate of lay; adversely affect efficiency of feed utilization and increase mortality. (Ambula *et al.,* 2003).

Digestibility and Energy Value of Sorghum Grain and Sorghum by-Products

The digestibility of cereals varies tremendously based on genetic background. 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 (Dowling *et al.,* 2002). 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. The digestibility of sorghum starch across the whole digestive tract of poultry is 99% compared with 87% for cattle. Within specie, age differences also affect digestibility of feed stuff (*Rowe et al*., 1999).

The overall total digestible nutrients in sorghum are roughly 95% of those in dry rolled yellowdent maize; this is due to lower starch availability because sorghum starch content varies and is bound in a thicker protein matrix. The chemical nature of the starch, particularly amylase 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. The actual dietary energy content of any feedstuff therefore will depend on its chemical composition since all organic components have an energy yielding value. 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 Ranjhan, 2001).

Starch and protein digestibility

Sorghum grain has the lowest raw starch digestibility due to restrictions in accessibility to starch caused by endosperm proteins. The digestibility of the starch, dependent on hydrolysis by pancreatic enzymes, determines the available energy content of cereal grain. The chemical nature of the starch, particularly the amylase and amylopectin content, is yet another factor that affects its digestibility. The starch digestibility reported to be higher in low-amylose, i.e., waxy, sorghum than in normal sorghum. The presence of tannins in the grain contributes to the poor digestibility of starch in some varieties of sorghum Tannins isolated from sorghum grain were shown to inhibit the enzyme X-amylose, and they also bind to grain starches to varying degrees. The low starch digestibility has also been attributed to a high content of dietary fiber. Lower starch digestibility has been reported in case of cooked sorghum flours than normal maize flour, irrespective of the endosperm type (Elkhalil *et al.,* 2001).

Digestibility in cooked sorghum flour has been attributed to the formation of disulphide bonds during cooking, which leads to toughening at the surface and interior of protein bodies. Both in vitro and in vivo studies have wide variability in protein digestibility of sorghum varieties. In certain sorghum varieties, the presence of condensed polyphenols or tannins in the grains is another factor that adversely affects protein digestibility and amino acid availability. A decrease in the protein digestibility of sorghum on cooking was attributed to reduced solubility of prolamin and its reduced digestibility by pepsin. Processing of the grain by methods such as steaming, pressure-cooking, flaking, puffing or micronization of the starch increases the digestibility of sorghum starch. This has been attributed to a release of starch granules from the protein matrix, rendering them more susceptible to enzymatic digestion.

The in-vitro digestibility of starch and protein in sorghum flours have been shown to be improved by cooking in the presence of reducing agents like cysteine, sodium metabisulphite, or ascorbic acid as the reducing agents minimize the formation of disulphide bonds. The in-vitro digestibility of sorghum proteins has been shown to have improved by fermentation. Fermentation is also reported to have led to an increase in lysine and methionine content. Protein digestibility of sorghum could also be improved by malting the grain. Malt pretreatment also resulted in a reduction in phytic acid content, which is a significant antinutritional factor. Germinated sorghum extract had a very low paste viscosity, while pretreatment of sorghum flour with small amounts of papain or trypsin enzymes lead to an improvement in the in vitro protein digestibility of sorghum, without affecting the paste viscosity (Suhendro *et al.,* 2000).

Anti-Nutritional Factors in Sorghum

Sorghum grain contains some anti-nutritional factors that makes it less digestible than maize (Etuk *et al.,* 2012). These anti-nutritional factors include the presence of tannin and phytic acids (Mohammad *et al*., 2011) which lowers the palatability, protein utilization and activity of digestive enzymes by non-ruminants (Medugu *et al.,* 2010a). Tannins also affect carbohydrate utilization by forming complex compound which are difficult to digest. Anti-nutritional factors may be grouped according to their mode of action as follows; Substances depressing digestion or metabolic utilization of protein. Phytic acid, oxalic acids, gluccosinolates and gossypol and Substances inactivating or increasing the requirements of certain vitamins, Anti-vitamins A, D, E and K, anti-thiamine, nicotinic acid, pyridoxine and cyanocobalamin. The anti-nutritional factors present in sorghum grain are tannin and phytic acid. Most parts of the sorghum plant are used as animal feed. Growing sorghum may be grazed, or the aerial parts of the plant may be ensiled or dried and fed as stover or silage for ruminant animals. Whole sorghum grain is cracked, ground, or steam flaked and fed to poultry, swine, dairy and beef cattle as a source of energy. Although not common, by-products of sorghum starch extraction such as hominy and gluten feed or gluten may also be fed to livestock (Akande *et al*., 2010; Maidala *et al*., 2013).

(AAFCO, 2009) defines sorghum gluten feed and gluten meal as follows: Grain Sorghum Gluten Feed is that part of the grain of grain sorghums that remains after the extraction of the larger part of the starch and germ, by the processes employed in the wet milling manufacture of starch or syrup. For proximate analysis of animal feeds, acid-detergent fiber (ADF) and neutral detergent fiber (NDF) are preferred to crude fiber analysis, particularly for ruminant feeds. These give an improved indication of the digestibility and the energetic feeding value of the feed, which is particularly important. Amino acids and fatty acids should be individually quantified. Among the fatty acids, linoleic is of key importance for sorghum grain. Tannin is the major anti-nutrient of concern in sorghum grain products, particularly bran, in varieties that contain tannins.

Patricia *et al.,* (2012) reported that there is diversity in chemical composition and anti-nutritional factors mainly tannin in the different varieties of sorghum resulting in variability in digestibility. Climatic, soil conditions, fertilizers are factors responsible for the variation in chemical composition of sorghum varieties (IAR, 2009; Etuk *et al*., 2012; Patricia *et al.*, 2012).

Tannins are well known as anti-nutritive factors that hinder the utilization of feeds by monogastrics animals especially poultry. Tannins depressed growth rate, reduced palatability and feed utilization by forming complexes with proteins and carbohydrates or inhibition of digestive enzymes. Unlike ruminant animals, poultry do not have microbes in their gastrointestinal tract to detoxify or reduce the effect of tannins, but several methods have been used to reduce the tannin content of poultry feeds for better utilization. These methods are mainly physical and chemical in nature. Tannins exert inhibitory effect on a broad spectrum of digestive enzymes at several sites in the digestive tracts of poultry. Feed conversion efficiency increased with increasing level of tannin up to 15g/kg diet while pancreatic and jejenal enzymes activities were not affected. This suggests that a wider range of factors may be involved in regulating the effect of tannins on poultry (Iji *et al.*, 2004; Ola *et al.*, 2005).

Kumar *et al.,* (2007) showed that tannin content of 16g/kg in red sorghum had no effect on nitrogen, calcium and phosphorus retention in broiler chickens. Similarly plasma albumin, globulin, protein, glucose, calcium, phosphorus, and uricacid levels were not affected even at 100% replacement of maize with red sorghum. The tannin sorghum varieties had low aminoacid digestibility and metabolisable energy compared with the non-tannin varieties, which suggests the anti-nutritional activity of the tannins. On the other hand, the tannin varieties had higher levels of antioxidants than the non-tannin varieties. White sorghum varieties are considered to be superior to red sorghum varieties by both pig and poultry nutritionists. While speculative, the superiority of white sorghums as a feed grain for poultry may simply be attributed to lesser concentrations of phenolic compounds.

Cyanogenic glycosides

Cyanogenic glycosides are mainly presenting erminating seeds, sprouts and the leaves of immature sorghum plants. Traore *et al.,* (2004) showed that malted red sorghum that had been dried contained on average 320 ppm cyanogens. The most abundant of cyanogen is dhurrin, which may comprise three to four percent of the leaves of germinating seeds (Waniska and Rooney, 2000). Stressors such as drought, frost, heavy insect infestation, or overgrazing can result in increased levels of these compounds, which, along with tannins, are part of the plants "defence mechanisms. The use of potassium nitrate fertilizer was also increase cyanogens production in sorghum (Busk and Moller, 2002).

In the stomach of livestock, cyanogenic glycosides may be converted into hydrogen cyanide, which is very toxic, and at low level chronic exposure may result in poor growth or reduced milk production. Processing of germinating seeds for feed may result in the release of cyanide. It is generally recommended not to graze animals on young plants or cut them for green chop until they are at least 18 to 51 cm tall (Undersander and Lane, 2001). However, traditional curing processes such as drying for hay, and malting processes of sprouts such as heating and drying, reduces the concentration of this toxin below a level of concern (Waniska and Rooney, 2000). With proper management, such as waiting until the plants have reached an appropriate height before grazing or harvesting, appropriate stocking rates, and good growing conditions, the levels of these compounds are low and do not pose a risk to livestock. Sorghum varieties developed specifically for grazing (*e.g.* Sudan grass) have low or non-detectable levels of cyanogenic glycosides (Waniska and Rooney, 2000).

Phytic acid

Like all grain species, sorghum contains phytic acid which binds minerals and reduces their availability to the consumer. Its phytic acid levels are similar to wheat, barley and maize, but lower than that of soybeans and other oilseeds. Since sorghum grain is usually low in mineral content (with phytin and mineral contents equivalent to maize), and the presence of phytic acid likely rendering its low mineral content unavailable, supplementation with other mineral sources is necessary where sorghum is a major component of the diet. As with tannin content, phytic acid content (and mineral content) may be reduced by abrasive decortication of the grain to remove the pericarp and aleurone layers. Phytate is invariably present in feedstuffs of plant origin and it is important negative factor inherent in grain sorghum. That phytate is an anti-nutritive factor in poultry diets is established and sorghum contains phytate at relative and absolute concentrations that are usually higher than other cereal grains (Waniska and Rooney, 2000).

The inclusion of phytate-degrading feed enzymes in poultry diets is routine but responses generated in sorghum-based diets appear to be muted. While speculative, the likelihood is that broiler chickens offered diets based on sorghums with low or modified kafirin levels coupled with low phenolic compound contents would respond more robustly to exogenous phytases.

The premise for this contention is that phytase simply cannot attenuate the anti-nutritive properties of these sorghum components. Another tangible benefit is that such sorghums could result in better pellet quality stemming from lower starch gelatinisation temperatures in sorghums with lesser concentrations of kafirin and phenolic compounds (Selle *et al*., 2003).

Phenolic compounds

Polyphenols and phenolic acids are important negative factors inherent in grain sorghum. It is improbable that other phenolic compounds are innocuous and devoid of anti-nutritive properties. Grain sorghum cultivars contain higher levels of phenolic compounds than other cereals and red (non-tannin) sorghums are highly pigmented with polyphenols (anthocyanins and anthocyanidins) and, importantly, these phenols bind strongly to starch. Condensed tannin is only partially responsible for variations in the nutrient quality of grain sorghum (Barros *et al.,* 2012).

Total Phenolic compounds tended to be negatively correlated with weight gain and N retention and positively correlated with FCR. The negative correlations with starch disappearance rates are noteworthy as the clear implication is that Phenolic compounds in sorghum are impeding starch digestion, glucose absorption and consequently energy utilization in poultry. Phenol compounds are believed to form complexes readily with starch and are probably more likely to form starch–phenol complexes with amylase than amyl pectin. It appears that phenol compounds may interact with starch through hydrogen bonds, covalent bonds or chelation via their carboxyl and hydroxyl groups (Yu *et al.,* 2001). Non-covalent interactions between starch and phenol compounds can influence the nutritional properties of feed stuffs (Kandil *et al.,* 2012).

Enzyme inhibitors

Sorghum contains protease inhibitors that specifically inhibit serine proteases such as trypsin and Chymotrypsin and most varieties also contain α-amylase inhibitors. These inhibitors are potent antifungal agents and are inactivated by germination and heat treatments (Waniska and Rooney, 2000).

Tannins

Different literature identified tannic acid as an anti-nutritional factor in sorghum grain. However, more recent research indicates that tannic acid is not a sorghum component (Dykes and Rooney, 2006). Some, but not all, sorghum varieties have pigmented testa containing condensed tannins, polyphenolic compounds that possibly give the seed a bitter taste and have been known to reduce intake, digestibility (particularly of protein), growth, and feed efficiency of livestock (Gilani, 2005; Waniska and Rooney, 2000). Sorghums are classified based on their tannin content: type I, no detectable tannin; type II, tannins in pigmented testa; type III, tannins in pigmented testa and pericarp (Waniska and Rooney, 2000).

Digestibility and utilization of absorbed nutrients may be reduced 3-15% by tannins. Tannins act as a plant defense against consumption by birds, and also provide some resistance to mold. In livestock production, tannins reduce the availability of key nutrients such as protein, energy, vitamins and minerals. Tannins are associated with the outer layers of the pericarp and testa of the sorghum kernel. White sorghum varieties without a pigmented testa are free of tannins. Red, brown, or black varieties may contain significant amounts of tannins, but only if they have a pigmented testa. The old varieties of sorghum grain contained relatively high amount of an anti-nutritional compound called tannin (Hancock, 2000; Ravindran *et al*., 2005; Sell *et al*., 2010).

Tannins are found in many different families of the higher plants and their content may be high in many foods of vegetable origin, including cereals, legumes, fruits, nuts and beverages, such as tea, wine and cocoa. As a consequence, they are an integral part of daily diet. Tannins have different biological effects in human and animal nutrition because of their ability to chelate metalions, form complexes with macromolecules and to act as antioxidants. They are able to form complexes with numerous types of molecules, including proteins, carbohydrates and enzymes involved in their digestion, polysaccharides and bacterial cell membranes; besides substances present in foods, tannins can bind endogenous proteins, such as digestive enzymes, inhibiting their activities. As a consequence, tannins reduce the digestibility of proteins, with a subsequent increase in fecal nitrogen excretion, affect the glycaemic and insulinemic responses and increase the fecal fat excretion. Tannins also affect the absorption of trace minerals by forming insoluble complexes in the gastrointestinal tract. Minerals chelated by tannins are not bioavailable for the organism, thus a diet based on consumption of large quantities of tannin-rich food, such as sorghum, is associated with minerals deficiency diseases, such as iron-deficiency anemia (Mamiro *et al*, 2005).

Treatment and Processing of Sorghum to Enhance its Nutritional Value

Early sorghum processing methods consisted essentially of chemical and mechanical detoxification as well as amino acid and mineral supplementation. However, during the last two decades processing sorghum grain by grinding, crumbling, pelleting, expanding, extruding, and steam flaking has become popular.

Grinding and hydro-thermal processing

Grinding grains before mixing into diets is thought to improve feed homogeneity, increase surface area for enzymatic degradation, and reduces selective feeding/sorting. However, results of particle size studies in broilers have shown conflicting results. In the U.S. broiler industry, cereal grains are usually ground through a hammer mill equipped with screens having openings of 4 to 5 mm (Behnke, 2009).

Pelleted diets improved weight gain and feed efficiency in broilers by 13 and 7%, respectively, compared to a mash diet. Fed broilers mash and crumbled sorghum-based diets pelleted or expanded at 85 ºC (Cramer *et al.*, 2003). Growth performance is similar for birds fed mash or crumbles. Starch gelatinization usually does not exceed 200 g/kg following steam conditioning and pelleting (Bryden *et al.*, (2009). The temperature at which sorghum starch gelatinizes (68 to 78ºC) exceeds that of corn (62 to 72ºC) and wheat (58 to 64ºC), implying that sorghum-based diets require a greater temperature during pelleting. However, pelleting sorghum-based diets at higher temperatures (82 to 90ºC) may induce the honey comb protein matrix to collapse. This collapse inhibits starch expansion, denies amylases access to their substrates, and reduces starch digestibility in cooked sorghum meal. Thus, there is little consensus about the need to pellet sorghum-based diets to maximize nutrient utilization and growth performance in poultry (Ezeogou *et al.*, 2008).

Whole sorghum added to pelleted rations for broilers by (Rogers *et al.,* 2009) who found that when compared to pellets made with ground sorghum, the birds fed pelleted rations with whole sorghum particles performed equally well. Another group has also presented work that indicates that whole sorghum can be added to poultry rations without negatively affecting growth. Biggs and Parsons (2009) fed rations with 10 and 20% whole sorghum and the birds at three weeks performed as well as those fed ground sorghum. The research work generally indicated that feeding whole grain as a portion of the diet would increase ME and amino acid availability.

However, the birds did tend to select the whole particles that could affect growth rate (Rodgers *et al*., 2009).

Methods of detoxifying tannins

In order to inactivate or reduce anti-nutrients in non-conventional feeds, have some simple processing methods (Babour *et al.*, 2001; Farran *et al.*, 2001). These strategies are broadly classified as physical and chemical methods.

Physical methods

Cooking

Effectiveness of cooking inactivates the activities of tannins. Cooking and soaking methods have used and the stability of anti-nutritional factors could be reduced by up to 15% when cooked for 45 min (Bressani, 2002).

Cooking is to reduce the anti-nutritional factors and thereby enhance the nutritional value of root and tuber crops (Agwunobi *et al.*, 2002; Akpan and Umoh, 2004). Tannin content 71.91% is destroyed after 30 minutes of cooking.

Also most of the anti-nutritional factors in legume seeds were destroyed after cooking the seeds for a minimum of 30 min (Balogun *et al.*, 2001). The anti-nutritional properties in sickle pod (*Cassia tora*) seed were reduced and safe for inclusion in livestock rations for optimum growth and development when the seeds cooked for 45 min (Buba *et al.*, 2010). No adverse effect in terms of performance of broiler chickens fed cooked diet. However, cooking in water for 60 min at100°C may denature protein making it unavailable and may induce loss of vitamins and minerals in legumes (Uchegbu *et al.*, 2008).

Soaking

Soaking as processing method to reduce tannin in non-conventional legume and cereal grains. 24 hrs soaking duration produced better results and would be preferred for tannin and cyanide in feed ingredients.

However, some metabolic reactions take place during soaking which will affect some of the constituents' compounds (Ahamefule and Odemelam, 2008).

Germination (Sprouting)

Germination has been documented to be an effective treatment to remove or reduce anti-nutritional factors in feedstuffs. Sprouting initiates three main types of chemical changes in the seed as follows; I) the breakdown of certain materials ii) transport of minerals from one part of the seed to another, especially from the endosperm to the embryo or from the cotyledons to the growing parts and iii) the synthesis of new materials from the break down product.

Depending on variety, total phenolic compounds in sorghum grain decreased upon germination. Condensed tannin located in the pericarp and testa, after germination (Torki and Farahmand-Pour, 2007) concluded that germinated sorghum grain could be better alternative for maize than in tact sorghum grain.

Dehulling

It has also been shown that the effect of tannins can be eliminated or neutralized by dehulling. It improved protein quality of *Phaseolus vulgaris* and suggested that this could be due to the removal of the seed coat tannin which may have caused decrease in protein digestibility (Bressani, 2002).

Autoclaving

Autoclaving is a more sophisticated, but effective method of processing seeds for eliminating anti-nutrient (Abeke and Otu, 2008). However, autoclaving is expensive because it requires adequate supply of electricity and technical knowledge.

Autoclaving of jack bean was satisfactory technique for ensuring survival of birds. They however, stated that there was little nutritional advantage in autoclaving of this product for more than half an hour (Kessler *et al.*, 1990).

Toasting/Roasting

Toasting involves dry heat treatment of legume bean seeds and other seeds for incorporation in poultry diets. Sometimes, some quantity of water is sprayed on the seed before they are toasted.

Toasting has been reported to effectively reduce the anti-nutritional factors of raw soybean which are associated with growth retardation in chickens (Akpodiete *et al.*, 2001). (Omoikhoje *et al.*, 2009) reported that inclusion of roasted fluted pumpkin pod husk waste increased broiler chicken performance and did not affect palatability of the diets (El-Boushy and Vandal Poel, 2001). A major problem of toasting may be that of charring of the seed if not property stirred (Abeke and Otu 2008).

Chemical methods

Use of wood ash

Wood ash, an alkaline substance is used by local people of south-Western Uganda to reduce tannins in red, bird resistant sorghum that is cultivated in that region. The effectiveness of the alkali treatment depends on the types and concentration of the alkali and the prevailing conditions. Soaking of high-tannin sorghum in wood ash extract was effective in reducing tannin level without lowering the nutrient content of the grain (Kyarisiima *et al*., 2004).

Addition of tallow (fat)

The mean Apparent Metabolisable Energy (AME) values of low-and high-tannin sorghums were 13.4 and 11.9 mg/kg respectively and observed that the nutritional value of high-tannin sorghums can be improved if its AME value is increased by the addition of animal fat.

Use of enzymes

The effectiveness of enzymes to enhance nutrient digestibility (Choct, 2006). Phytase improves phosphorus utilization in poultry (Oyango *et al.*, 2005; Ravindran *et al.*, 2006). Supplementation of feeds for broiler chickens with phytase has improved growth and bone mineralization and decrease mortality. However, Torki and Farahmand-Pour (2007) observed no significant effect of enzyme supplementation on performance of broiler chickens fed sorghum based diets.

Urea treatment

Feeding with jack bean meal containing tannins treated with urea solution involving young broiler chicks demonstrated that jack beans so processed could be tolerated by broiler chicks up to 25% inclusion level in the diet without adverse effects on performance (Akinmutimi *et al.,* 2000).

Enzymes for sorghum based diets

Most cereal grains and poultry benefit to some extent by the addition of enzymes that either increase nutrient availability or decrease the impact of anti-nutritional factors for example, the use of glucanase enzymes to mitigate the negative effect of viscosity in wheat and barley. Sorghum, with possible anti nutritional factors and difficult to digest protein layers would seem a good candidate for enzymes to improve feeding values. Adding enzymes to the diet of poultry depends on many factors, including the type and amount of cereal in the diet; the level of anti-nutritive factor in the cereal, which can vary with in a given cereal; the spectrum and concentration of enzymes used; the type of bird and their age (young bird tend to respond better to enzymes than older birds) (Lobo, 2000).

Sorghum Production and Productivity in Ethiopia

The presence of wild and cultivated sorghums in Ethiopia reveals that Ethiopia is the primarycenter of origin and centre of diversity (Mekibeb, 2009). The diversity of sorghum, studying genetic diversity and biochemical composition of sorghum germplasm from Ethiopia is very important for several reasons (Ayana, 2001).

The low productivity of sorghum in the developing countries can be attributed to biophysical, socio-economic and policy related factors affecting directly and indirectly sorghum production. Agriculture is a driver of the Ethiopian economy (FDRE, 2009).

It is run by small holder majority who undertake subsistence mode of life. Despite its importance, agriculture suffers from low productivity. Crops are playing a significant role and it is believed that adoption of new agricultural technologies, such as high yielding varieties, could lead to significant increases in agricultural productivity and stimulate the transition from low productivity subsistence agriculture to a high productivity agro-industrial economy (World Bank, 2008). Several improved crop varieties have been developed by the national and international research institutes and disseminated to the farmers through different programs and projects. The diverse crop varieties released that are under production in Ethiopia can be found in the Variety Register developed by the Ministry of Agriculture (MoA, 2012).

In sub-Saharan Africa, agricultural production is dominated by cereal-based systems. According to the Central Statistics Authority of Ethiopia (CSA, 2008), sorghum ranks third after maize and teffin total production, after maize in yield per hectare and after tef and maize in area harvested, but current studies, Sorghum is the fourth primary staple food crop in Ethiopia after tef, maize, and wheat, both in area coverage, and production (CSA, 2012).

In the country cereals comprise78.23% (8.8 million ha) of the field crops of which sorghum accounts for 14.41%. In Ethiopia sorghum is grown in almost all regions occupying an estimated total land area of 1.6 million ha (CSA, 2012). The major sorghum production regions of Ethiopia are Oromia at 38.5%, Amhara (32.9%), Tigray (14.1%), and Southern Nations and Nationalities People (S.N.N.P.) region (7.6%). Sorghum is usually grown in arid and semi-arid parts of the tropics and sub-tropics where it is affected by drought during various growth stages (Amjad *et al.,* 2009).

The growth and yield of Sorghum, one of the major crops in these dry land regions of Africa, is often limited by drought. In the dry land environments, drought is not only the result of limited annual rainfall, but is also due to the rainfall characteristics, mainly the delay in the onset and early cessation of the main rainfall.

The national average sorghum productivity in Ethiopia is 2.1tons/ha (CSA, 2012) which is far below the global average of 3.2 tons/ha (FAO, 2005). This is because of a number of factors. Several productions constraints were identified as in hindrance for sorghum production and productivity enhancement.

The major constraints include drought, insect pest, diseases, and soil fertility decline, inadequate adoption of existing improved varieties, lack of high yielding and good quality sorghum varieties, and post-harvest management practices.

Management practices such as sowing date, row spacing, sowing density, cultivar choice (both seasonal length and genetic traits), soil water availability, and fertilizer application are factors to enhance productivity. Variability of rainfall (onset, intensity, and cessation) as well as temperature, day length, and solar irradiance are important climatic factors that also impact management practices.

Ethiopia has a diverse wealth of sorghum germplasm adapted to a range of altitudes and rainfall conditions. Of the five morphological races of sorghum (bicolor, guinea, caudatum, durra and kafir), all, except kafir, are grown in Ethiopia. Important traits reported from the Ethiopian sorghum include cold tolerance, drought resistance, resistance to sorghum shoot fly, disease and pest resistance, grain quality and resistance to grain mould, high sugar content in the stalks, and high lysine and protein content.

Sorghum is one of the major staple crops grown in the poorest and most food insecure regions of Ethiopia. The crop is typically produced under adverse conditions such as low input use and marginal lands. It is well adapted to a wide range of precipitation and temperature levels and is produced from sea level to above 2000 m.a.s.l.

Its drought tolerance and adaptation attributes have made it the favorite crop in drier and marginal areas. Ethiopian is often regarded as the centre of domestication of sorghum because of the greatest genetic diversity in the country for both cultivated and wild forms (Fetene, 2011).

Recommendation

Sorghum is an important cereal crop and plays a key role in animal feed and human. Although it is similar to maize in chemical composition sorghum has great drought tolerance and requires minimal fertilizers on marginal lands for cultivation, tolerate soil toxicities and temperature extremes effectively than other cereals.

Sorghum contains some anti-nutritional factors especially tannin which inhibit the use of important nutrients like protein, energy and minerals (phosphorus, calcium, zinc and magnesium) in diets.

Cereal grains like maize and sorghum constitute the major sources of energy in poultry diets. The major cost of production of egg and meat in commercial poultry production is feed.

Based on the above conclusion the following recommendation are forwarded.

Develop diets which allow locally available cereal ingredient like sorghum that can meet the energy requirement of the birds.

Reduce the tannin content of poultry feeds.

Use improved varieties of sorghum.

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