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# Polyphenols in Sorghum, Their Effects on Broilers and Methods of Reducing Their Effects: A Review

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ABSTRACT

Polyphenols in sorghum are commonly known as tannins. Tannins in sorghum have negative effects such as reducing voluntary feed intake, digestibility and slow growth rate. Protein digestibility is one of the major nutrients affected by tannins. Tannins forms protein-tannin complex which reduces digestibility of protein, slows growth rate and sometimes affects formation of amino acids. Tannins can be easily be treated if they are hydrolysable tannins, these can be reduced their effects through soaking in water to allow sorghum grains to absorb water. Condensed tannins can be removed through dehulling, heat treatment and the use of high temperatures to remove sorghum coat. Sorghum can be used as a close substitute of maize in broiler diets and reduce pressure of maize on stock feed and used as staple food. If tannins in sorghum can be easily removed, sorghum becomes the best source for animal feed.

**Keywords:** Polyphenols; Sorghum; Tannins; Broilers; Methods of Reducing Tannins

## Introduction

Sorghum has many sub species and races of which kaffir is the most commonly grown in the Southern African region Dogget [1]. The race kaffir includes both white and red varieties which are low and high tannin content varieties. Developing varieties suitable to SADC region is being undertaken at the SADC-ICRISAT research at Matopos (Zimbabwe). SV1 and SV2 have been recently released. These two are highly yielding, open pollinated, with white grains and without testa. Both varieties are susceptible to bird damage Mushonga et al. [2,3], Red Swazi ,a brown sorghum was locally bred and first released in 1978. It is an open pollinated variety, drought resistant and matures early. There is less bird damage in Red Swazi and it is not susceptible to moulds Mushonga [2].

### Nutritional Composition

Sorghum grain consists of 8% pericarp; an embryo of about 10% and the rest is mainly endosperm Hulse et al. [4]. Some sorghum has a hard and vitreous endosperm while others have a soft and floury endosperm. Sorghum that is floury has a brown pericarp and is pigmented. High tannin sorghum has a prominent pigmented testa of varying thickness and it is located beneath the pericarp. The testa is formed from the inner integument and a pair of complementary genes controls its presence. Several authors have reported the proximate composition of different African and other sorghum varieties Oria et al. [4, 5] reported protein ranges from 8.9% to 16.6%; crude fat 2.5% to 5.1%; crude fibre 1.3% to 3.5% and ash 1.1% to 2.5% as compared to maize which contains 7.9% crude protein ,4.3% crude fat,1.9% crude fibre and 1.6 ash. Oria et al. [6] found that there was little variation between analyzed varieties in ash; crude fat and fiber content but found major differences in protein and tannin content. Peripheral cells have a high protein content and resists both physical and enzymatic degradation this region also provides some protection to the underlying endosperm cells which are richer in starch Oria et al. [7].

### Polyphenols in Sorghum

Polyphenols are very large heterogeneous group of compounds that occur in combination with sugar or analogous compounds either as glycosides or as phenol esters Nyamambi et al. [8]. Seeds of numerous sorghum varieties contain tannins, primarily of the condensed type, which are associated with a pigmented testa underlying the pericarp. Only the white variety of sorghum

is tannin free Dogget [1].The polyphenols in sorghum affect the colour, appearances and nutritional quality of the grain and sorghum products. These tannins are found in the testa. The phenolic compounds can be divided into 3 basic groups; phenolic acid, flavonoids and tannins. Tannins are divided into 2 subgroups according to their effects in animal nutrition and the groups are hydrolysable tannins (H.T) and condensed tannins (C.T). Today, most agree that hydrolysable tannins, if present, are found only in trace quantities and that condensed tannins are responsible for the bulk of protein binding activity. Condensed tannins are condensation products of flavan –3; 4-diols with some incorporation of flavan -3 -ols, primarily catechin or epicatechin. They are the compounds most for reactions attributed to tannins Mushong [2].

In high tannin varieties, the phenolic group of these procyanidins constitutes a large proportion of the phenols present in the grain. The production of tannin containing sorghum is of economic importance in the livestock industry and as a food source. Polyphenols in sorghum have been associated with lower nutritive value and lower biological availability of macromolecules like protein, carbohydrates, amino acids, vitamins, lower protein efficiency ratio and weight gain Dogget [1]. On the other hand, tannins defend plants from herbivores, provides resistance to bird damage, resistance to weathering, preharvest germination and moulding .The repellency of sorghum by birds is due to stringent caused by coagulation of salivery proteins and mucous epithelium when in contact with tannins Oria et al. [5].These grains can therefore be used in broiler diets Weaver et al. [9].

## Effects of Polyphenols on Energy Content and Digestibility

Starch in sorghum grains occur in the endosperm enmeshed in a protein matrix. In waxy sorghum most of the starch is amylo pectin, whereas in non-waxy sorghum it is amylose. The digestibility of starch is affected by the composition, and physical form of the feed or food material, and starch protein interaction. Waxy types have higher digestibility than non-waxy types Nyamambi et al. [8]. Tannins in sorghum are also known to reduce both total and protein digestibility and to inhibit activity of amylase enzymes thereby reducing energy content availability. Tannins present in brown varieties reduce starch digestion. Sorghum that have higher proportions of peripheral endosperm are less digestible as they can resist both physical and enzymatic degradation Nyamambi et al. [8]. Digestibility of a starch is generally inversely proportional to amylase content Nyamambi et al. [8]. Interaction with protein can reduce the susceptibility of both native and processed starch to enzymes hydrolysis. Antinutritional factors affecting starch utilization include enzyme inhibitors, plytates, lections and tannins. The tannins bind proteins and inhibit some enzymes systems and may effectively reduce starch digestion.

Polyphenols are known to interfere with certain essential biochemical processes including the “uncoupling” of the oxidative phosphorylation essential to the synthesis of ATP, and this may in part explain the impaired utilization of carbohydrates by animals fed high tannin, sorghum Hulse et al. [4]. The positive and negative effects, of condensed tannins (proanthoyanidins) in sorghum and other seed crops may have a common basis. The only well-established biochemical effects of these materials are that of protein binding and precipitation, which accounts for the astringent and enzyme inhibitory properties of tannins. The cell wall of cereals is comprised primarily of complex carbohydrates, which are loosely termed non-starch polysaccharides Anniston et al. [10]. Lately considerable evidence has been gathered indicating that cereal non starch polysaccharides possess antinutritive activity when present even at lower levels in broiler diets Anniston et al. [10].

Water treatment has been used to remove the water-soluble non starch polysaccharides (pentosans and B-glucans) and the activation of endogenous enzyme capable of degrading the polysaccharides, but the improvement is dependant on the concentration of the water soluble non starch polysaccharides in the cereal Anniston et al. [10]. Bird resistant or high tannin varieties have lower energy values than lower tannin varieties. Sibbald (1976) reported T.M.E values of 14.14mj/kg for high tannin and 16.19mj/kg for low tannin varieties. White varieties have even more than low tannin varieties because they are tannin free. Effects of polyphenols on protein and amino acid availability and digestion. Sorghum is a good source of total protein compared with other cereals grown in the tropics. However, the protein quality appears to be one of lowest of the major cereals with regard to its lysine content (2.2%) Oria et al. [5] and true digestibility of (85.3%) for sorghum and (90.2%) for maize in pigs. The tannins in the sorghum can bind dietary proteins forming protein-tannin complexes, which are resistant to attack by proteolysis enzymes. There are varietal differences in protein content and digestibility. Waxy sorghum contains 100% amyl pectin as opposed to 75% amyl pectin; 25% amylase in non-waxy sorghum. Tannin content has been found to be closely correlated with amino acids availability. Tannin level had no effect on lysine availability but generally all amino acids are less available in high tannin sorghum Oria et al. [5]. Sorghum protein in normal cultivars is less digestible because the protein bodies are more resistant to proteolysis than the protein bodies of other similar cereal grains such as maize Oria et al. [6]

There is enough tannin in high tannin sorghum to precipitate more protein than is in the grain. The relative nutritive value of sorghum is improved by germination. Germination of the sorghum grain resulted in a consistent increase in the albumin fraction, which is rich in lysine and in other amino acids FAO [11]. Sorghum grain contain proline, rich protein that interact strongly with tannin and may to some extent protect other dietary and digestive protein from interaction with tannin Oria et al. [5] obtained much lower invitro digestibility for high tannin sorghum than for that in low tannin sorghums. When tannin was extracted there was an improvement in digestibility from 4% to 5% to 17%. Weaver et al. [9] however

found these results questionable as the reduction in chick growth fed on diets with those sorghums with high tannin content were not that correspondingly low. Several authors reported low protein digestibility's after carrying out in vitro studies of digestibili Oria et al. [6].

The effect of tannin were more manifest on protein and amino acids digestibility when low/ sub-optimal levels were fed to poultry Weaver et al. [9,12] reported that when tannin is added to the diet in the form of tannin acid, amino acid digestibility decreases and when added to protein free diets there was significant increase in excretion by 6.6 times Oria et al. [6]. Removal of tannins either by chemical or mechanical means improved protein digestibility. Dehulling of sorghum increased digestibility by 71% and reduces tannin content to 0.2% catechin equivalent (CE) Burns [13] Boiling sorghum grains decreased protein digestibility and the amount of protein present in boiled sorghum. Dehulling results in a considerable loss of protein. Amino acid analysis of the dehulled grain showed a progressive decrease in the content of the lysine, hystidine and arginine. Dehulling low tannin varieties is accompanied by a decrease in the relative levels of the albumins and globulins while there is a two-fold increase in the relative content of the Kafirin fraction, which is predominantly derived from protein bodies that are slightly more concentrated in the interior of the seed.

## Effects of Polyphenols on Broilers

The depressed growth rates in chickens fed rations based on grain sorghum has been studied extensively. Hulse et al. [4] showed that the possible cause of retardation was the high tannin content of some grain. Presence of tannins in some sorghum cultivators (Red Swazi) has been associated with depression of growth rate, feed intake, protein digestibility, metabolizable energy and also with leg abnormalities in chickens Tropical Agriculture [14]. This could explain the significant reduction in live weight gain and food conversion ratio observed in birds fed sorghum. Rate of gain and efficiency of feed utilization of broilers were unfavorable in broilers fed 100% substitution with sorghum Tropical Agriculture [14,6] reported that levels of 0.6 to 0.83% (dry matter) tannin acids in the diet were sufficient to significantly depress chicken performance. When high lysine sorghum were fed to chicks, the chicks grew 3 times more rapidly and ate half as much feed as these fed normal sorghum Oria et al. [6]. A level of 2 to 4% tannic acid reduced feed intake and egg production Weaver et al. [9]. Introducing forms of tannic dietary and other polyphenols into the diet at a level of 2% was reported to be toxic Oria et al. [6].

## Detoxification of Polyphenols

Polyphenols may be detoxified chemically or mechanically. However, such treatments must be in expensive , easy to use and have no detrimental effects on the product. A number of methods have been used to try overcome problems associated with high tannin sorghums Banda-Nyirenda et al. [15], some of which are discussed below.

**Mechanical Method (Mechanical Abrasion):** In most parts of the world , sorghum grain is first dehulled before use as human food Hulse et al. [4] Mechanical abbrassion is an effective way to remove polyphenols as they occur in the testa. This method has been shown to result in 37% loss of the grain and sorghum with soft endosperms are rather difficult to dehull as such seeds tend to break resulting in loss of the fine endosperm to hull fraction and up to 45% loss in protein content as well as the removal of most of the tannins up to 98% Chibber et al . [16]. Mechanical abrasion, therefore leads to higher protein losses when high tannin sorghums were mechanically dehulled to remove tannins Chibber et al. [16] also showed that there was a reduction in tannin content from 4.5% to 0.2% catechin equivalents. Protein was lost during the dehulling process and the reduction was from 9.4% to 8.2%. Milling also increased the percentage starch content and reduced the percent protein content Chibber et al. [16,6] also reported significant declines in fat, fibre and ash with dehulling and only tannin in the high tannin variety declined.

**Alkali Treatment:** Extraction of tannins with aqueous alkali resulted in marked improvements in weight gain and feed efficiency of rats, chickens Banda-Nyirenda et al. [15] and improved invitro protein digestibility Chavan et al. [16]. Up to 85% of the tannins are extracted in 20 mins when the sorghum seeds are soaked in aqueous alkali at 100 degrees celsius while only 30% of tannins are removed when soaked in distilled water. Dry matter loss to the treatment with alkaline reagent ranged from 1.2- 2.3% Gomez et al. [17,18]. compared different alkalis and found that all alkalis used could remove up to 90% of the tannin in the grain. Dilute solutions, however required a longer time to reduce the tannin content. Price et al. [19,20] demonstrated that adding dry CaO reduced tannin content instantaneously rather than gradually like other alkalis. Higher temperatures reduced the amount of tannin in a shorter time. At 30 degrees Celsius, 31% was removed in 24hrs and at 100 degrees Celsius only 20mins was required to reduce the same amount Gomez et al. [18]. Reichert assayed tannin in different sorghum and grain components and showed that 81.6% of the condensed tannins was in the testa and 15.1% in the pericarp Nyamambi et al. [8] Increasing the concentration of sodium hydroxide from 0.005 to 0.05 improved the efficiency of removal of tannin from 36% to 84%.Treatment such as cooking with acid or alkali fermentation and malting have been shown to modify endosperm cell walls and protein matrix exposing starch granules to enzyme action.

Method of Tannin Analysis: Various methods have been used for analysis of tannins. Colorimetric methods are widely used mainly due to their simplicity and high sensitivity; these include Folin-CiO calten, Folin- Denis, Vanillin- HCL assay for catechins Gomez et al. [18] and butanol-HCL assay for proanthocyanidims. Lately

attention has been focused on quantitative tannins based on their property of binding proteins, as both the ecological and biological roles of tannin are attributed to the complexation of tannin with protein. Moreover, protein precipitation assays of tannins are highly correlated with the biological value of tannin rich food and feed.

**Vanillin Assay:** This is a substitution reaction where polyphenols with several groups in alternate positions, undergo substitution reaction very easily. It was modified over the years until Burns [12] suggested the use of hydrochloric acid instead of sulphuric acid in the procedure absolute methanol for extracting the phenolic compounds. When some sorghums were extracted with absolute methanol assayable tannin was detected yet when the extraction was done with 1% HCL in methanol Chavan et al. [17]. Problems associated with this method include the problem of extraction. There is no single extraction method that extracts all condensed tannins Gomez et al. [18].This method is affected by the particle size and the relative humidity during storage also affect assayable tannins.

## Conclusion

Sorghum is a source of energy hence feeding broiler with sorghum as a partial substitute of maize reduces competition on maize. The presence of low tannin sorghum varieties such as SV1 makes sorghum a suitable cereal grain to be fed to broilers since this does not affect broiler growth at when introduced as partial substitutes of maize. Red Swazi has a potential of being used as a partial substitute of maize in broiler diets due to its advantages which includes resistant to moulds, preharvest and bird destraction. Waxy type sorghums can be actually used because of there high digestibilities. Reducing tannin content through dehulling is the best measure , but it also reduces protein content.

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