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Research Application Summary

Domain of anti-nutritional factors in sorghum: A perspective of livestock nutrition

Awori, E.[1,3], Mwije, A.[1], Kabi, F. [1], Niwagaba, P.[1], Obua, T.[1], Dramadri, I.[1], Ndapewa, S.[1], Chelangat, D.M.[1], Akeni, I.[1], Cruet-Bourgos, C.[4], Kena, A.[4], Nuwamanya, E.[1], Kaketo, R.[2], Scovia, A.[2] & Odong, T.L.[1]

[1]Department of Agricultural Production, College of Agriculture and Environmental Sciences, Makerere University, P. O. Box 7062, Kampala, Uganda

[2]National Semi-Arid Resources Research Institute, P.O. Box 56, Soroti, Uganda

[3]Abi Zonal Agriculture Research and Development Institute, P.O. Box 219, Arua Uganda

[4]Soil and Crop Sciences, College f Agricultural Sciences, Colorado State University, USA

Corresponding author: ekawori@gmail.com

Abstract

Tannins and dhurrin (cyanogenic glucoside) are the two main anti-nutritional elements of sorghum. However, other antinutritive compounds including phytoestrogens, phytates (phytic acid), and alkaloids can also affect the quality of feed if they are not managed. While tannins are a polyphenolic compound found in grains, dhurrin is a cyanogenic glucoside that is mostly present in aerial shoots and sprouted seeds. Phytoestrogens are phenolic compounds found in small amounts in the stems, seeds, and bran layers of the sorghum grain. Salts of esters called phytates are present in grains. The most common phytoestrogens found in sorghum are lignans. The intestinal absorption of dietary and endogenous amino acids as well as the digestibility of proteins can all be hampered by tannin and phytates. Tannin also has the ability to complex proteins in the gut. Dhurrin reduces oxygen intake, causing animals to have breathing difficulties, grasping, convulsions, and even paralysis. On the other hand, when ingested in sufficient amounts by animals, phytoestrogens bind to minerals like calcium, iron, and zinc in the digestive tract, reducing their bioavailability. Oxalates bind to calcium and magnesium in livestock feed, reducing their bioavailability. Lower serum calcium and magnesium levels result from fodder that contains more alkaloids. As a contribution to lessen impact of sorghum antinutritional factors on animal nutrition, this review examines the principal anti-nutritional component of sorghum, its significance in livestock nutrition, current breeding, and biotechnology as well as crop management techniques.

Key words: Alkaloids, Dhurrin, Phytoestrogens, Phytates, Tannins

Résumé

Les tannins et le dhurrine (glucoside cyanogène) sont les deux principaux éléments anti-nutritionnels du sorgho. Cependant, d'autres composés anti-nutritionnels, tels que les phytoestrogènes, les phytates (acide phytique) et les alcaloïdes, peuvent également affecter la qualité de l'alimentation s'ils ne sont pas gérés. Alors que les tannins sont des composés polyphénoliques trouvés dans les grains, le dhurrine est un glucoside cyanogène présent principalement dans les pousses aériennes et les graines germées. Les phytoestrogènes sont des composés phénoliques présents en petites quantités dans les tiges, les graines et les couches de son du grain de sorgho.

Les phytates, des sels d'esters, sont présents dans les grains. Les phytoestrogènes les plus courants trouvés dans le sorgho sont les lignanes. L'absorption intestinale des acides aminés alimentaires et endogènes ainsi que la digestibilité des protéines peuvent être entravées par les tannins et les phytates. Les tannins ont également la capacité de complexer les protéines dans l'intestin. Le dhurrine réduit l'apport en oxygène, provoquant des difficultés respiratoires, des convulsions et même des paralysies chez les animaux. D'autre part, lorsqu'ils sont ingérés en quantités suffisantes par les animaux, les phytoestrogènes se lient aux minéraux comme le calcium, le fer et le zinc dans le tractus digestif, réduisant leur biodisponibilité. Les oxalates se lient au calcium et au magnésium dans les aliments pour animaux, réduisant leur biodisponibilité. Des niveaux sériques plus bas de calcium et de magnésium résultent d'un fourrage contenant plus d'alcaloïdes. Afin de contribuer à réduire l'impact des facteurs anti-nutritionnels du sorgho sur la nutrition animale, cette revue examine les principaux composants anti-nutritionnels du sorgho, leur importance dans la nutrition animale, les techniques actuelles de sélection et de biotechnologie ainsi que les techniques de gestion des cultures.

Mots-clés: Alcaloïdes, Dhurrine, Phytoestrogènes, Phytates, Tannins

Background

Lack of access to high-quality fodder to make up for dry season shortages is the main obstacle to cattle production in Africa (Balehegn *et al.,* 2022). The ability of sorghum to improve the performance of dryland cattle has been acknowledged on a global scale (Abreha et al., 2022). Sorghum is different from other major cereal crops in that it can be economically produced in hot, dry conditions, thus allowing for its full utilisation in both human and cattle diets (Ali *et al.,* 2014). According to Getachew *et al.* (2016), when cultivated for fodder, sorghum yields are comparable to maize with sweet and forage sorghums having high biomass yield potential of 20 to 40 dry Mt ha^{-1}. Sorghum's heterotic mechanisms allow it to produce more biomass and yield components than other cereals, raising the prospect that it could take the place of maize in areas with scarce water supplies (Boyles *et al.,* 2017).

Being a C4 plant, sorghum has a high water use efficiency, using 332 L of water per kilogramme of dry matter accumulated as opposed to maize's 368 L, barley's 434 L, and wheat's 514 L (Getachew *et al.,* 2016). Sorghum's waxy leaves further contribute to its low transpiration rate, which further increases its drought tolerance (Martin, 2016). The crop can absorb moisture from deeper soil layers because to its vast root system, which exhibits a predominance of vertical growth even in juvenile stages(Sirohi *et al.,* 2021) and final depths of up to 200 cm (Xu *et al.,* 2018). Studies have also demonstrated the significance of sorghum's nodal root angle for drought tolerance and stay-green traits, as well as a remarkable capacity to absorb nutrients (Abreha *et al.,* 2022). Furthermore its high tolerance to high salinity (Yukun *et al.,* 2021), ability to grow on poor soils within a pH range of 5.0 to 8.5 (Derese *et al.,* 2018), and tolerance to water logging (Promkhambut *et al.,* 2010) all continue to point to sorghum as the best choice of dry season forage for Africa in the face of climate change.

However, forage sorghum has low protein and starch digestibility (Sattler *et al.,* 2010; Tetreault *et al.,* 2021) and high Neutral Detergent Fibre (NDF) with high lignin concentration (Drew, 2015), which reduces nutritional bioavailability. According to Martin (2016), sorghum starch granules are closely related to endosperm proteins (kafirins), which limit the accessibility of -amylase, rendering the proteins scarcely digestible. Additionally, sorghum has antinutritional factors that can significantly reduce feed quality (Adler *et al.,* 2015; Cowan *et al.,* 2022; Nakasagga *et al.,* 2022). These antinutritional factors were divided into three distinct categories by Etuk *et al.* (2012). The first category includes substances that hinder protein digestion or metabolic utilisation, such as protease inhibitors, lectins (haemagglutinins), saponins, and polyphenolic compounds (tannins, cyanogenic glucosides); ii) substances that inhibit or reduce the absorption of mineral elements, such as phytic acid, oxalic acids, glucosinolates, and gossypol and iii) substances that deactivate or increase the need for specific vitamins, such as anti-vitamins A, D, E, and K, antithiamine, nicotinic acid, pyridoxine, and cyanocobalamin, some of which have several modes of action.

This implies that having all nutritional factors present in forage is not enough but their bioavailability is crucial for maximum utilisation by livestock. Therefore, this review aims to elucidate anti-nutritional factors present in forage sorghum, their overall effect on livestock nutrition, mitigation measures as well as current breeding and biotechnology approaches in managing them.

Approach

The review was conducted mainly through literature such as from scholarly journal article on antinutronal factors downloaded from different search engines including Google scholars and other onlines sources. Some electronic books were also reviewed for relevant literature concerning antinutritional factors in sorghum.

Results and Discussion

Adding methyl group donors like choline and methionine to livestock feed can help to mitigate tannin-related issues (Etuk *et al.,* 2012). Tannin concentration in plants can also be reduced through intercropping, soil nutrition, and stress prevention. A known SNP (S4_62316425) in the TAN1 gene, a regulator of tannin accumulation in sorghum grain can also be manipulated (Wu et al.,2012). In order to control dhurrin levels in forage sorghum, genes that are involved in the production of dhurrin (CYP79A1, CYP71E1, UGT85B1, and POR), bioactivation (DHR1, DHR2, DHR-like3, DHR-like4; HNL), prevention of auto-toxicity (CAS, NIT), and endogenous recycling (GST lambda candidates and NIT4A/NIT4B2) during the organ and plant development phases can also be altered. Furthermore, two cytochrome P450s involved in detoxification of dhurrin can also be employed to manage dhurrin levels in forage sorghum. Ensiling (fermentation) and heat treatment are two processing techniques that can break down phytates and increase the availability of minerals for absorption, lowering the amount of phytates in forage sorghum. Additionally, animals with additional mineral intake in their diets can assist in making up for the decreased mineral bioavailability in forage with a high phytate level. This guarantees that the animals eat properly.

Animals feeding forage sorghum can benefit from balanced diets that take into account the mineral-binding properties of phytates. The majority of anti-nutritional elements in forage sorghum are thought to be age- and plant-material-dependent(Gleadow *et al.,* 2021; Nakasagga *et al.,* 2022). Additionally, it is claimed that proper processing of the forage sorghum greatly lessens the impact of these anti-nutritional elements on the nutrition of animals. The generation of feed sorghum cultivars with the right amounts of anti-nutritional elements to increase cattle productivity is now possible because of recent advancements in sorghum mutational breeding. Therefore, finding the right time to harvest forages, developing new varieties with low levels of anti-nutritional factors, and selecting the right processing methods all appear to have a positive impact on the quantity and potency of these anti -nutritional factors in sorghum. Ruminants generally have unique digestive systems that can metabolize phytoestrogens differently compared to non-ruminants like pigs and poultry (Adler *et al.,* 2015). In ruminants, microbial activity in the rumen may partially degrade phytoestrogens, thus reducing their impact on the animal. Pregnant or lactating animals may be more sensitive to phytoestrogen effects.

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