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Replacing corn with sorghum in diets for fattening pigs

Sustitución de maíz por sorgo en dietas para cerdos de engorda

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ABSTRACT
The objective of this paper is to make known and clarify that sorghum in pig diets can replace corn in their feed due to its nutritional characteristics and the type of improved varieties that contain a lower concentration of anti-nutritional factors. It is necessary to disseminate information about the nutritional properties of sorghum among producers, so that they have the possibility of a wider range of ingredients. In conclusion, the inclusion of sorghum as an energy ingredient in the diet of pigs can replace up to 100% of corn.
Keywords: porciculture, *Sorghum bicolor*, *Zea mays*.

RESUMEN
El objetivo del presente escrito es dar a conocer y aclarar que el sorgo en dietas de cerdos puede sustituir al maíz debido a sus características nutricionales y al tipo de variedades mejoradas que contienen menor concentración de factores antinutricionales. Es necesario difundir la información acerca de las propiedades nutricionales del sorgo entre los productores, para que cuenten con un abanico más amplio de ingredientes. En conclusión, la inclusión de sorgo como ingrediente energético en la dieta de cerdos puede sustituir hasta el 100% del maíz.
Palabras clave: porcicultura, *Sorghum bicolor*, *Zea mays*.

INTRODUCTION

In the Mexican livestock sector, maize is the primary energy ingredient used in the feed manufacturing industry for livestock species, while sorghum is the second most widely used energy source in the formulation of feeds for animals of zootechnical importance. Globally, sorghum is the fifth most cultivated cereal grain after wheat, maize, rice, and barley. Mexico accounts for 3.2% of the world's harvested sorghum area, making it the fifth-largest producer (Carbajal-García *et al*., 2018; CONAFAB, 2023). Sorghum is a multipurpose crop used as a source of fuel, bioethanol, alcoholic beverages, and construction materials. It is one of the most important food crops in arid and semi-arid regions worldwide, whereas in developed countries it is cultivated primarily for forage and animal feed (Ananda *et al*., 2020).

Sorghum is an ingredient with excellent nutritional value for swine due to its energy content, amino acid profile, and fatty acid composition, and it can be used as the primary cereal grain in diets for all stages of production. However, over time, sorghum consumption has largely depended on the price paid by end users for the grain, the market prices of maize, wheat, and soybean, as well as the availability of livestock sectors such as dairy cattle, swine, and poultry for meat and egg production, which rely on grain-based feeds (Rebollar *et al*., 2016). When sorghum is properly processed and diets are appropriately formulated to provide adequate concentrations of nutrients (e.g., energy, phosphorus, and digestible amino acids), it can serve as a cost-effective alternative to maize, wheat, or barley.

Nutritional Characteristics of Sorghum

All sorghum varieties contain phenolic acids, and most also contain flavones; however, "brown" sorghum varieties have higher concentrations of condensed tannins, which are primarily located in the pericarp. High-tannin (brown) sorghum cultivars are commonly grown in arid regions because of their agronomic advantages, including resistance to drought, bird damage, insect attack, and fungal infestation. One of the major limitations of sorghum utilization is that nutrient digestibility decreases as tannin concentration increases due to the formation of tannin–protein and tannin–carbohydrate complexes, which impair the activity of pancreatic enzymes. At tannin concentrations ranging from 0.3 to 0.7%, the reduction in digestibility is relatively small; however, when tannin levels exceed 1%, the decrease becomes significant (Barros *et al*., 2012). Consequently, high tannin concentrations negatively affect the digestive utilization of amino acids. Pan *et al*. (2016) reported a negative correlation between the metabolizable energy value of sorghum and its condensed tannin content, estimating a reduction of approximately 200 kcal/kg of metabolizable energy (ME) for each 1% increase in tannin concentration. Accordingly, high tannin levels (1.0–1.4%) may reduce growth rate by approximately 4% and feed efficiency by about 8% in growing pigs (Goodband *et al*., 2016).

There are sorghum varieties containing less than 0.2% tannins, which are more widely used in diets for finishing pigs and have a nutritional value comparable to that of maize. Table 1 presents a comparison of the energy value of white sorghum, brown sorghum, and maize. The nutritional value of white sorghum is superior to that of high-tannin varieties, with improvements of approximately 10–15% in crude protein (CP) digestibility and 5–10% in energy value. Overall, sorghum varieties provide approximately 98–99% of the energy value of maize (FEDNA, 2019). Furthermore, the inclusion of glucanases and xylanases in sorghum-based diets can increase the amount of metabolizable energy available to the animal (Oliveira *et al*., 2022).

Table 1. Nutritional comparison of sorghum versus corn

%	**White Sorghum*†**	**brown sorghum****	**Corn***
PC	8.90	8.97	7.30
Tannis	<0.40	>0.40	NS
PC Digestibility	75.00	73.70	80.00
EE	3.00	2.35	3.30
Moisture	13.00	14.10	13.6
Crude fiber	2.30	2.78	2.10
NDF	8.80	9.80	9.00
ADF	4.50	4.60	2.80
Starch	64.20	56.8	63.80
oleic fatty acid	0.80	-	0.80
linoleic fatty acid	1.20	1.13	1.66
Linolenic fatty acid	0.10	-	0.03
Calcium	0.03	0.03	0.03
Total P	0.28	0.26	0.25
Fítico P	0.19	0.18	0.20
available P	0.07	0.08	0.06
ME (Mcal kg^{-1})	3330	2984	3370
lysine	0.20	0.20	0.22
Metionina	0.15	0.15	0.15
Methionine+Cystine	0.32	0.30	0.31
threonine	0.29	0.29	0.27
Tryptophan	0.10	0.10	0.06
Isoleucine	0.35	0.36	0.26
Valine	0.45	0.44	0.35
Arginine	0.35	0.35	0.33

*FEDNA (2019). ** Brazilian Tables for Poultry and Swine (2017). †Low tannin variety. CP: crude protein. EE: ethereal extract. NDF: neutro detergent fiberADF: acid detergent fiber. P: phosphore. Ca: calcium. ME: metabolizable.energy. NS: No significat.

The crude protein (CP) content of sorghum (8.9%) is higher than that of corn (7.3%), providing greater amounts of tryptophan, valine, threonine, isoleucine, and arginine, although it contains lower levels of lysine (Araiza-Piña *et al*., 2003). In addition, low-tannin sorghum varieties improve CP digestibility in swine diets (Pan *et al*., 2022). Although sorghum is often considered inferior because of its lower lysine content (0.20%) compared with corn (0.22%), this difference can be compensated by supplementing diets with synthetic lysine or by increasing the inclusion level of soybean meal. Moreover, although sorghum varieties have been bred for higher lysine content (up to 52% above the average), these cultivars generally exhibit low grain yield. Likewise, sorghum varieties combining high lysine content with low tannin concentrations have been developed; however, they are also characterized by poor agronomic productivity.

Sorghum protein is composed of approximately 54% kafirin, a storage protein with low digestibility due to the presence of cysteine residues that form insoluble disulfide bonds, which are negatively correlated with the grain's energy value. Nevertheless, the reduced protein digestibility of sorghum can be mitigated through dietary supplementation with protease enzymes (Liu *et al*., 2013). Likewise, the use of synthetic amino acids allows the formulation of least-cost diets based on sorghum without compromising their nutritional adequacy.

An important characteristic from both an economic and environmental perspective is that sorghum grain contains a higher phosphorus concentration (0.28%) than corn (0.25%). Consequently, the inclusion of phytase enzymes can further enhance phosphorus digestibility in sorghum-based diets compared with corn-based diets (Almeida *et al*., 2017), thereby reducing the need for supplemental inorganic phosphorus. This, in turn, decreases phosphorus excretion in swine manure, contributing to a lower environmental impact.

Replacement of Corn with Sorghum in Finishing Pig Diets

The use of low-tannin sorghum varieties combined with fine grinding can achieve growth and finishing performance in pigs comparable to that obtained with corn, allowing both grains to be used interchangeably without compromising productive (Goodband *et al*., 2016; Bauza *et al*., 2018). The FEDNA (2019) recommends limiting the inclusion of sorghum throughout the different production stages, suggesting its exclusion from pre-starter diets and maximum inclusion levels of 12% in starter diets, 40% for lactating sows, and 45% for finishing pigs and gestating sows. However, several studies have demonstrated the feasibility of replacing corn with sorghum. Based on more than 25 years of research evaluating sorghum–soybean meal diets for pigs during the starter, growing, and finishing phases. Figueroa-Velasco *et al*. (2022) concluded that such substitution is a viable feeding strategy. Complete replacement of corn with low-tannin sorghum in nursery and growing pig diets does not adversely affect growth performance or the apparent digestibility of gross energy, although it tends to reduce the apparent digestibility of crude protein, resulting in greater fecal nitrogen excretion (Pan & An, 2020a; 2020b; Pan *et al*., 2021a).

Nevertheless, even at low concentrations, tannins remain an antinutritional factor that can limit nutrient utilization in swine diets. Replacing corn with sorghum may alter intestinal morphology and reduce the activity of digestive and antioxidant enzymes, potentially decreasing energy and nitrogen utilization as well as feed efficiency, particularly in pigs during the early stages (Pan *et al*., 2021b).

Agronomic Aspects and Grain Processing

One of the main agronomic advantages of using sorghum in swine nutrition is its lower susceptibility to mycotoxin contamination compared with corn. Under certain climatic conditions and high disease pressure, corn may accumulate elevated concentrations of mycotoxins, whereas sorghum generally presents a lower risk. In addition, sorghum is an attractive alternative to corn because of its superior drought tolerance and lower water requirements, making it particularly suitable for regions with limited water availability (FEDNA, 2019).

However, sorghum also has some limitations. Its kernels are small (approximately 4 × 2 × 2.5 mm) and considerably harder than corn kernels, requiring fine grinding to improve nutrient digestibility. Excessive grinding, however, produces a high proportion of fines, resulting in dusty feed with reduced palatability. Different particle sizes of ground sorghum (320–800 µm) have been evaluated to determine their effects on the productive performance of finishing pigs. Although particle size has generally shown no significant effect on average daily gain or carcass quality, a finer particle size (320 µm) has been associated with improved feed conversion efficiency (Paulk *et al*., 2015).

CONCLUSIONS

Sorghum represents an excellent alternative for swine producers and commercial feed manufacturers to reduce feed costs, enabling ingredient selection based on economic opportunity rather than concerns regarding antinutritional factors. Research evaluating the complete replacement of corn with sorghum has consistently demonstrated that low-tannin sorghum can be reliably incorporated into diets for growing–finishing pigs without compromising productive performance, providing confidence in its use as a viable substitute for corn.

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