Journal of Animal Prod., 37, https://rpa.reduc.edu.cu/index.php/rpa/article/view/e316

Husbandry and Nutrition

Review article

Use of Henequen (*Agave fourcroydes* Lem.) as a Nutraceutical Additive in Animal Feed

Ana Julia Rondón Castillo *, Marlen Rodríguez Oliva *, Marta Laurencio Silva *

*Center for Biotechnological Studies. University of Matanzas, Cuba.
Correspondence: ana.rondon@umcc.cu

Received: October 2025; Accepted: December 2025; Published: April 2026.

ABSTRACT

Background: Henequen (*Agave fourcroydes* Lem.) is well known in Cuba for its use in fiber production for ropes and cords. In recent years, however, its agroindustrial residues have begun to be considered for direct dietary supplementation or for the production of nutraceutical additives aimed at improving animal nutrition. **Aim.** To evaluate the effects of using this plant, either as a feed ingredient or as a nutraceutical additive, on productivity and health in species of zootechnical interest. **Development:** The chemical composition of *Agave fourcroydes* was found to be characterized by a high carbohydrate content (84.02%). Only a small fraction of these carbohydrates is utilized by animals because of their low degradability; nevertheless, the presence of fructans gives the plant residues biotechnological interest due to their potential use as nutraceutical additives in animals of zootechnical relevance. Dietary supplementation with these compounds improved production, fermentation, microbiological, immunological indicators, and overall health in ruminants, pigs, rabbits, and broiler chickens. **Keywords:** feed additives; inulin; agroindustrial residues (Source: *AGROVOC*)

INTRODUCTION

The common definition of a functional food or nutraceutical is an ingredient that provides physiological benefits beyond basic nutrition. So-called specialized, prescription, or veterinary diets not only meet an animal's nutritional requirements but, through the inclusion of additives, also confer beneficial effects on the organism — for example, improved intestinal health and enhanced immune function — among others (AlAli *et al*., 2021).

The ban on antibiotics as growth promoters, concerns about antimicrobial resistance, and consumer demand for animals raised without drugs and for high-quality food products pose challenges for producers seeking alternative methods to control and prevent pathogenic infections. Nutraceuticals offer a valuable solution as feed additives, primarily through their host-

Citations (APA) Rondón Castillo, A. J., Rodríguez Oliva, M., & Laurencio Silva, M. (2026). Use of Henequen (*Agave fourcroydes* Lem.) as a Nutraceutical Additive in Animal Feed *Journal of Animal Prod*, *37*. https://rpa.reduc.edu.cu/index.php/rpa/article/view/e316

protective functions, including antioxidant, anti-inflammatory, antimicrobial, and cell-survival effects, with the goal of improving productivity (Buonaiuto *et al*., 2025).

Trujillo-Ramírez *et al*. (2023) report on the comprehensive use of henequen (*Agave fourcroydes* Lem.) Their work highlights the growing use of this plant as a functional feed ingredient for animals. The authors indicate that bioactive compounds such as fructans, flavonoids, and sterols can be obtained from the henequen stem and incorporated into diets to improve productivity and animal health. Fructans are considered prebiotics — non-digestible substances that are selectively utilized by host microorganisms and that confer health benefits. (Gibson *et al*., 2017)

In Cuba, henequen production generates large volumes of pulp (wet bagasse and juice), with up to nine tons of residues produced per tons of fiber processed. This means that only about 4–11% of the henequen leaf is used for fiber extraction, resulting in substantial pulp volumes; for example, an annual fiber output of 1,700 tons (t) produces 15,300 t of organic pollutants, with negative environmental impacts (Gutiérrez *et al.*, 2020).

Several researchers report that henequen pulp or meal is a promising nutraceutical additive because of its prebiotic activity (Iser *et al*., 2020). The aim of this review is to evaluate the effects of using the agroindustrial residues of this plant, either as a feed ingredient or as a nutraceutical additive, on productivity and health in livestock species.

DEVELOPMENT

Chemical and nutritional composition of *Agave fourcroydes*

Tables 1 and 2 present the results of research by del Toro *et al*. (2016), who determined the proximate composition and characterized the fiber fractionation of stem meal from *Agave fourcroydes*. The authors concluded that the meal exhibited suitable physical properties, low crude protein (CP) content, and high dry matter and fructan levels—qualities that make this material a promising nutraceutical candidate for animal diets.

Table 1. Basic proximate composition of *Agave fourcroydes* stem meal (HTAF) Dry matter (del Toro *et al*., 2016).

Ïtems (%)	HTAF	SE (±)
Dry matter	95.29	0.68
Crude protein	6.01	0.15
Ethereal extract	0.06	0.01
Ashes	5.20	0.33
Carbohydrates	84.02	0.03

Standard deviation (SD)

Table 2. Fiber fractionation of *A. fourcroydes* stem meal (del Toro *et al*., 2016)

Indicators (%)	HTAF	SD±
NDF	16.27	0.76
ADF	8.50	0.85

Lignin	0.43	0.09
Cellulose	15.82	0.25
Hemicellulose	7.77	0.60

Standard deviation (SD)

Iser *et al*. (2020) determined the secondary metabolites, quality indicators, and organoleptic characteristics of stem meal from *Agave fourcroydes* (henequen) grown in Cuba. Their results showed that coumarins predominated in the ether extract, while flavonoids and anthocyanidins were the main constituents of the ethanolic extract. In the aqueous extract, alkaloids, saponins, flavonoids, mucilages, and reducing carbohydrates were present only in low amounts. The plant material had a slightly acidic pH (5.18), a refractive index of 1.33, a bulk density of 0.31 $g \cdot mL^{-1}$, an acidity of 0.76%, and 1.50 °Brix soluble solids in water. The organoleptic properties of *A. fourcroydes* stem meal were described as having a good physical appearance, partial solubility, good grindability, light-beige color, pleasant odor, slightly sweet taste, and good homogeneity. According to the authors, *A. fourcroydes* stem meal could be evaluated as a nutraceutical product in farm-animal diets.

The presence of secondary metabolites such as coumarins activates a variety of biological activities, including antibacterial, anti-inflammatory, and antioxidant effects (Annunziata *et al*., 2020; Shegute & Wasihun, 2020; Zeki & Mustafa, 2024). Flavonoids are known to reach the intestine largely undegraded, where they can exert important functions such as antioxidant activity, anti-inflammatory properties, modulation of the gut microbiota, immunomodulation, and prevention of coccidiosis (Orzuna-Orzuna *et al*., 2023; Onu *et al*., 2024). Anthocyanidins, for their part, protect animals from oxidative stress (Tian & Lu, 2022; Sadowska-Bartosz & Bartosz, 2024).

All of these studies support the results of numerous investigations aimed at evaluating the effect of these agroindustrial residues on animal nutrition or their biotechnological use to obtain nutraceutical additives that enhance productivity and health in livestock species.

Use of Agave fourcroydes as animal feed

Martínez *et al*. (2021) evaluated the effect of dietary supplementation with *Agave fourcroydes* powder (1.5% of the diet) in 40 weaned male rabbits (New Zealand × Californian cross) weaned at 35 days of age. After 60 days, *A. fourcroydes* powder increased body weight, feed intake, and weight gain ($P<0.05$) without affecting feed conversion ratio or viability ($P>0.05$). In addition, the product lowered cecal pH and, consequently, increased beneficial cecal bacteria ($P<0.05$). *A. fourcroydes* powder also reduced serum concentrations of glucose, harmful lipids, and the atherogenic index ($P<0.05$), while blood urea nitrogen and creatinine remained unchanged ($P>0.05$).

Gutiérrez *et al*. (2020) conducted an experiment to nutritionally evaluate henequen bagasse (*Agave fourcroydes*) for use in ruminant feeding. They used the *in situ* nylon-bag incubation technique in two cannulated Siboney crossbred cows. Chemical composition results showed a low dry matter (DM) content (12.55%); however, organic matter (OM) and crude protein (CP) contents were considered acceptable. Crude fiber was moderate (23.60%), which contributed to good digestibility values: DM digestibility 63.62%, OM digestibility 65.8%, and an estimated metabolizable energy of 9.54 MJ·kg DM^{-1}. The degradability parameters were: soluble fraction a = 28.6%, insoluble but potentially degradable fraction b = 39%, and potentially degradable fraction a + b = 72.96%. The fractional degradation rate c = 6% h^{-1}. Effective degradability (ED) at passage rates k = 0.02 and k = 0.08 was 60% and 43%, respectively. Rumen-degradable protein (ERDP) was high (67%; 59.18 g·kg DM^{-1}) and rumen-undegradable protein (UDP) was lower (27%; 23.98 g·kg DM^{-1}). The authors concluded that henequen bagasse could be used as an animal feed residue, particularly for ruminants.

Presence of prebiotic substances in *Agave fourcroydes*

In modern animal production, the use of prebiotics such as fructans is increasing; these compounds can function as growth-promoting additives because of the benefits they confer to animal health and productive performance. *Agave* species contain considerable concentrations of these compounds, and the structural characteristics of these carbohydrates can influence the animal response (García-Curbelo *et al*., 2015; Hernández-Montesinos *et al*., 2024).

The inulin content in henequen pulp is around 15–20% (Higuera Ramírez, 2009) and in the piñas it can reach up to 29% (Ferrer-Serrano *et al.*, 2024). This prebiotic compound is used by gut bacteria as an energy source. In this regard, García-Curbelo *et al.* (2007) demonstrated *in vitro* that two probiotic strains of *Lactobacillus salivarius* (7 and 65) and a probiotic mixture fermented inulin. The results showed that all strains tested utilized inulin as an energy source. The authors suggest these properties could support future work to develop synbiotic products that would enhance these effects.

Production of bioproducts from henequen

In Cuba, fructans were obtained from the stems of *Agave fourcroydes* (henequen) as a prebiotic additive for use in livestock production (García-Curbelo *et al*., 2015). This bioproduct was chemically characterized and shown to retain physical stability for six months and chemical stability of the active principle for up to 12 months when stored at room temperature (García-Curbelo *et al.*, 2022).

Hurtado *et al.* (2022) developed a biological product to evaluate the characteristics of a fermented *Agave fourcroydes* extract as an additive for ensiling. The fermentation showed stability at 24 h with a pH of 3.87, together with observed variations in temperature and °Brix. The bioproduct contains 15% dry matter, 47% crude protein (dry basis), and is characterized by the presence of lignocellulolytic microorganisms, predominantly *Penicillium* spp. and *Bacillus subtilis*. Producing bioproducts from henequen extract and using them as silage inoculants represents a sustainable, cost-effective alternative to preserve feeds without affecting their nutritional value.

The presence of minerals in the pulp ensures the availability of Ca, Zn, Fe, Cu, and Mn, which are recognized as promoters of fermentative activity because they act as cofactors in many enzymatic systems. They are also natural sources of oligofructans, considered among the best substrates for lactic-acid bacteria compared with high-degree-of-polymerization fructans; their heterogeneous structure and composition facilitate fermentation and microbial growth (Mercedes & Herrera, 2012). All these factors could contribute to the development of higher-quality, more stable silages.

Effect of the fructans present in henequen as a nutraceutical additive in animals of zootechnical interest

The effects of fructans from *Agave fourcroydes* were also evaluated in broiler chickens. A total of 525 mixed-sex birds from the EB34 breeder line were used in a completely randomized design with three treatments: control (standard corn-soy diet), and the standard diet supplemented with 0.25% or 0.50% *A. fourcroydes* fructans. The main results were stimulation of fermentative activity in the cecum and increased abdominal fat deposition. Only the 0.50% treatment stimulated the immune response, evidenced by an increased relative weight of the bursa of Fabricius, which was associated with higher antibody titers to the Newcastle vaccine and an increase in live weight (García-Curbelo *et al.*, 2020). According to these authors, the use of prebiotic additives helps maintain eubiosis in the gastrointestinal tract, which increases nutrient digestibility and allows greater absorption, thereby contributing to muscle development.

García-Curbelo *et al*. (2015) conducted an experiment to evaluate the effect of fructans from *Agave fourcroydes* on production indicators of tilapia (*Oreochromis niloticus*) during early developmental stages. Groups receiving fructans showed survival rates above 90%, greater biomass gain (g), and improved feed conversion. These conditions enabled the fish to enter the development–grow-out phase with better production indicators.

The results presented in this work demonstrated the prebiotic activity of fructans from *Agave fourcroydes*, since their structural characteristics prevent them from being hydrolyzed or absorbed in the upper parts of the gastrointestinal tract, allowing them to reach the large intestine where they serve as an energy source for beneficial microorganisms such as lactobacilli and bifidobacteria—an aspect that was shown in *in vitro* studies. *In vivo* studies in pigs, broiler chickens and tilapia confirmed the prebiotic-type biological response of *A. fourcroydes* fructans, which supports their use as an additive in animal feed.

Rondón *et al*. (2019) obtained a synbiotic additive by combining henequen pulp (rich in inulin, a prebiotic) with PROBIOLACTIL® (a probiotic culture of *Lactobacillus salivarius* C65) for use in feeding calves during the weaning and rearing phase. These authors demonstrated that inclusion of this additive improved live-weight indicators, average daily gain and weight increase from day 21 onward, and positively affected health by reducing the incidence of diarrhea. The biopreparation—designed by applying a probiotic culture to agroindustrial residues and enriched with locally available components—constitutes a synbiotic product that can be used as a nutritional additive in calves.

García-Curbelo *et al*. (2018) carried out a study to evaluate the effects of agavins from *Agave fourcroydes* on lipid-metabolism indicators in growing pigs. Inclusion of agavins in the diet decreased serum cholesterol levels ($P = 0.0172$), which was associated with a reduction in low-density lipoproteins ($P = 0.0091$), and also reduced total lipids ($P = 0.0254$). The prebiotic-treated groups showed no differences in triglyceride levels, high-density lipoproteins, very-low-density lipoproteins, or live weight of the animals.

Hernández-Granados *et al*. (2021) evaluated the effects of dietary supplementation with *Bifidobacterium animalis*, *Agave fructans*, and an encapsulated synbiotic of both on growth performance, feed efficiency, blood parameters, and immune status in broiler chickens, and compared them with diets that included antibiotic growth promoters. Alternative treatments were shown to have productive results similar to those of antibiotics and showed improvements compared with the additive-free diet. However, these additives have immunomodulatory properties and improve development of the gastrointestinal tract compared with the treatment that used antibiotic growth promoters.

CONCLUSION

Research on the use of *Agave fourcroydes* residues in animal production has focused mainly on their use as a source of prebiotic substances, given the potential of fructans to activate the microbiota and thereby stimulate the immune system, increase nutrient digestibility, reduce the incidence of pathogenic microorganisms, and consequently improve the health and productivity of animals of zootechnical interest.

REFERENCES

AlAli, M., Alqubaisy, M., Aljaafari, M. N., AlAli, A. O., Baqais, L., Molouki, A., Abushelaibi, A., Lai, K. S., & Lim, S. E. (2021). Nutraceuticals: Transformation of Conventional Foods into Health Promoters/Disease Preventers and Safety Considerations. *Molecules (Basel, Switzerland)*, *26*(9), 2540. https://doi.org/10.3390/molecules26092540

Annunziata, F., Pinna, C., Dallavalle, S., Tamborini, L., & Pinto, A. (2020). Una descripción general de la cumarina como un andamio versátil y fácilmente accesible con actividades biológicas de amplio alcance. *Revista Internacional de Ciencias Moleculares*, *21*(13), 4618. https://doi.org/10.3390/ijms21134618

Buonaiuto, G., Danese, T., El-Sabrout, K., & Yıldırım, A. (2025). Bioactive feed additives in animal nutrition: bridging innovation, health, and sustainability. *Front. Vet. Sci.*, *12*, 1727126. https://10.3389/fvets.2025.1727126

del Toro, M.I., Martínez, Y., Valdivié, M., Sánchez, D., & Jiménez, C. (2016). Caracterización físico-química de la harina de tallos de *Agave fourcroydes* Lem (Henequén). REDVET. *Revista Electrónica de Veterinaria*, *17*(10), 1-13. https://www.redalyc.org/articulo.oa?id=63647454007

Ferrer-Serrano, C. M., de Cárdenas, B., & Mestre, M.M. (2024). Extraction of inulin from waste pineapples of Cuban henequen plants. *Journal of Clinical and Laboratory Research*, *7*(5). https://doi.org/10.31579/2768-0487/133

García-Curbelo, Y., Ayala, L., Bocourt, R., Albelo, N., Nuñez, O., Rodríguez, Y., & López, M.G. (2018). Agavinas como prebióticos: su influencia en el metabolismo lipídico de cerdos. *Cuban J. Agr Sci.*, *52*(4), 395-400. https://cjascience.com/index.php/CJAS/article/view/844/873

García-Curbelo, Y., Bocourt Salabarría, R., López Pérez, M. G., Albelo Dorta, N., & Núñez Peñalver, O. (2022). Estudio de estabilidad de un prebiótico constituido por fructanos de Agave fourcroydes para su utilización como aditivo en la ganadería. *Revista de Salud Animal*, *44*. https://cjascience.com/index.php/CJAS/article/view/71

García-Curbelo, Y., Bocourt Salabarría, R., Rodríguez Sánchez, B., Albelo Dorta, N., Albelo González, A., Herrera Villafranca, M., & López Pérez, M. (2020). Prebiotic effects of agavins in poultry. *Livestock Research for Rural Development*, *32*(8). https://www.lrrd.org/lrrd32/8/yanelys32122.html

García-Curbelo, Y., Boucourt, R., Albelo, N., & Núñez, O. (2007). Fermentación de inulina por bacterias ácido lácticas con características probióticas. *Cuban J. Agr Sci.*, *41*, 263. https://www.redalyc.org/pdf/1930/193017693011.pdf

García-Curbelo, Y., Llanes, J., Toledo, J., Albelo, N., & Bocourt, R. (2015). Evaluación de fructanos de *Agave fourcroydes* (FRUCTOICA) en postlarvas de tilapias del Nilo GIFT (*Oreochromis niloticus*). *AcuaCUBA*, *17*(1), 23-27. https://www.lrrd.cipav.org.co/lrrd29/1/curb29008.html

García-Curbelo, Y., López, M., Bocourt, R., Rodríguez, Z., Urias-Silva, J., & Herrera, M. (2012). *In vitro* fermentation of the extract of *Agave fourcroydes* (henequen) by lactic acid bacteria. *Cuban J. Agr Sci.*, *46*(3), 203-209. https://cjascience.com/index.php/CJAS/article/view/71

Gibson, G.R., Hutkins, R., Sanders, M.E., Prescott, S.L., Reimer, R.A., Salminen, S.J., Scott, K., Stanton, C., Swanson, K.S., Cani, P.D., Verbeke, K., & Reid, G. (2017). Expert consensus document: The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of prebiotics. Nature reviews. *Gastroenterology & hepatology*, *14*(8), 491-502. https://doi.org/10.1038/nrgastro.2017.75

Gutiérrez, D., Aguirre, L., Ortiz, B., Lima R., Rodríguez, Z., González, A., & Elías A. (2020). Nutritional assessment of bagasse of *Agave fourcroydes* (henequen) for use in animal feed. *Bosques Latitud Cero*, *10*(1), 29-38. https://revistas.unl.edu.ec/index.php/bosques/article/view/716

Hernández-Granados, M.J., Ortiz-Basurto, R.I., Jiménez-Fernández, M., García-Munguía, C.A., & Franco-Robles, E. (2021). Dietary encapsulated *Bifidobacterium animalis* and *Agave* fructans improve growth performance, health parameters, and immune response in broiler chickens. *Anim. Biosci*., *35*(4), 587-595. https://doi.org/10.5713/ab.21.0213

Hernández-Montesinos, A.J., Alfonso González, D., Coronado Acosta, D., Reyes Fernández, R., & Rodríguez Alfonso, D. (2024). Determination of fructans in vegetative organs of *Agave Offoyana* (Asparagaceae) and its potential use as a prebiotic. *Cuban J. Agr Sci*., *58*. https://cu-id.com/1996/v58e26

Higuera Ramírez, A.I. (2009). Evaluación del efecto prebiótico del aguamiel de Maguey en *Lactobacilus delbrueckii* subsp. *bulgaricus*. *Tesis (Maestro en Ciencias en Bioprocesos)*, Instituto Politécnico Nacional, SEPI, UPIBI. https://api.semanticscholar.org/CorpusID:130749219

Hurtado, B.Y., Lima Orozco, R., Casanova Cosío, E., & Gutiérrez González, D. (2022). Extracto de *Agave fourcroydes* fermentado como aditivo para ensilajes. *Revista Universidad y Sociedad*, *14*(4), 125-130. https://rus.ucf.edu.cu/index.php/rus/article/view/3029/2980

Iser, M., Valdivié, M., Figueredo, L., Nuñez, E., Más, D., & Martínez, Y. (2020). Secondary metabolites, quality indicators and organoleptic characteristics of stems meal from *Agave fourcroydes* (henequen). *Cuban J. Agr Sci.*, *54*(1), 1-10. https://cjascience.com/index.php/CJAS/article/view/937

Martínez, Y., Iser, M., Valdivié, M., Galindo, J., & Sánchez, D. (2021). Supplementation with *Agave fourcroydes* powder on growth performance, carcass traits, organ weights, gut morphometry, and blood biochemistry in broiler rabbits. *Revista Mexicana de Ciencias Pecuarias, 12*(3), 756-772. https://doi.org/10.22319/rmcp.v12i3.5892

Mercedes, G. L., & Herrera, M. (2012). In vitro fermentation of the extract of Agave fourcroydes (henequen) by lactic acid bacteria. *Cuban Journal of Agricultural Science*, *46*(2). https://cjascience.com/index.php/CJAS/article/view/71

Onu, E.O., Ugwoke, J.I., Edeh, H.O. Onu, M.C., & Onyimonyi, A.E. (2024). A review: Flavonoid; A Phyto-nutrient and its impact in livestock animal nutrition. *World Journal of Advanced Research and Reviews*, *21*(01), 311-320. https://doi.org/10.30574/wjarr.2024.21.1.2701

Orzuna-Orzuna, J. F., Dorantes-Iturbide, G., Lara-Bueno, A., Chay-Canul, A. J., Miranda-Romero, L. A., & Mendoza-Martínez, G. D. (2023). Meta-analysis of flavonoids use into beef and dairy cattle diet: Performance, antioxidant status, ruminal fermentation, meat quality, and milk composition. *Frontiers in veterinary science*, *10*, 1134925. https://doi.org/10.3389/fvets.2023.1134925

Rondón, A. J., del Valle, A., Milián, G., Arteaga, F. G., Rodríguez, M., Valdivia, A., & Martínez, M. (2019). Obtención de un biopreparado simbiótico (mezcla de pulpa de Agave fourcroydes Lem. y PROBIOLACTIL®) para su aplicación en terneros. *Agrisost*, *25*(2), 1-9. https://doi.org/10.5281/zenodo.8410973

Sadowska-Bartosz, I., & Bartosz, G. (2024). Antioxidant Activity of Anthocyanins and Anthocyanidins: A Critical Review. *International Journal of Molecular Sciences*, *25*(22), 12001. https://doi.org/10.3390/ijms252212001

Shegute, T., & Wasihun, Y. (2020). Antibacterial activity and phytochemical components of leaf extracts of *Agave americana. J. Exp. Pharmacol.*, *3*(12), 447-454. https://doi.org/10.2147/JEP.S258605

Tian, X., & Lu, Q. (2022). Anthocyanins in Dairy Cow Nutrition: A Review. *Agriculture*, *12*(11), 1806. https://doi.org/10.3390/agriculture12111806

Trujillo-Ramírez, D., Bustos-Vázquez, M. G., Martínez-Velasco, A., & Torres-de los Santos, R. (2023). Integral use of henequen (*Agave fourcroydes*): applications and trends–a Review. *Tropical and Subtropical Agroecosystems*, *26*(2). http://doi.org/10.56369/tsaes.4619

Zeki, N.M., & Mustafa, Y.F. (2024). Coumarin hybrids: a sighting of their roles in drug targeting. *Chem. Pap.*, *78*, 5753-5772. https://doi.org/10.1007/s11696-024-03498-z

AUTHOR CONTRIBUTION STATEMENT

Research conception and design: AJRC, MRO, MLS; data analysis and interpretation: AJRC, MRO, MLS; manuscript writing: AJRC, MRO, MLS.

CONFLICT OF INTEREST STATEMENT

The authors state there are no conflicts of interest whatsoever.