CHARACTERIZATION OF SWINE PRODUCTION SYSTEMS IN THE USE OF AGRO-INDUSTRIAL BY-PRODUCTS AND NON-TIMBER FOREST RESOURCES IN ANIMAL FEED

CARACTERIZACIÓN DE LOS SISTEMAS DE PRODUCCIÓN PORCINA EN EL USO DE SUBPRODUCTOS AGROINDUSTRIALES Y RECURSOS FORESTALES NO MADERABLES EN LA ALIMENTACIÓN ANIMAL

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Summary

The constant growth of humankind leads to a greater demand for raw material to guarantee the food security of the population, which is why it is sought that animal food sources do not compete with human food; facing this challenge, nutritional alternatives based on the use and exploitation of non-timber forest resources and agro-industrial resources are proposed with the objective of improving the productive parameters and profitability of swine production systems through actions that have an impact on their cost structure. In summary, the purpose of this research was to characterize the swine production systems in the use of AR (palm kernel cake - *Elaeis guineensis* and cocoa husk - *Theobroma cacao*) and NTFR (*Cratylia Argéntea*, *Piptocoma Discolor*, *Oenocarpus Bataua and Mauritia Flexuosa*) in animal feed in the state of Caquetá based on a non-experimental methodological approach with a descriptive-transactional scope and a mixed approach where the main data collection instrument was a survey applied to 44 producers. It should be emphasized that 93% of the producers do not make use of NTFR and Agro-industrial by-products due to the lack of knowledge of the potential of these resources in feeding, hence 90% of the production systems are backyard, presenting as main problems the high costs of inputs and low production triggering a low profitability and low level of technification.

Key words: Nutritional alternatives, NTFR, Swine production systems and Agro-industrial by-products.

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Resumen

El constante crecimiento de la humanidad conduce a una mayor demanda de materia prima para garantizar la seguridad alimentaria de la población, por lo que se busca que las fuentes de alimentación animal no compitan con la alimentación humana; Ante este desafío, se proponen alternativas nutricionales basadas en el uso y aprovechamiento de recursos forestales no maderables y recursos agroindustriales con el objetivo de mejorar los parámetros productivos y la rentabilidad de los sistemas de producción porcina a través de acciones que incidan en su estructura de costos. En resumen, el propósito de esta investigación fue caracterizar los sistemas de producción porcina en el uso de AR (torta de palmiste - Elaeis guineensis y cáscara de cacao - Theobroma cacao) y NTFR (Cratylia Argéntea, Piptocoma Discolor, Oenocarpus Bataua y Mauritia Flexuosa) en alimentación animal en el estado de Caquetá a partir de un enfoque metodológico no experimental con un alcance descriptivo-transaccional y un enfoque mixto donde el principal instrumento de recolección de datos fue una encuesta aplicada a 44 productores. Cabe recalcar que el 93% de los productores no hace uso de NTFR y subproductos Agroindustriales por el desconocimiento del potencial de estos recursos en la alimentación, por lo que el 90% de los sistemas de producción son de traspatio, presentándose como principales problemas los altos costos de los insumos y la baja producción desencadenando una baja rentabilidad y bajo nivel de tecnificación.

Palabras clave: Alternativas nutricionales, ARFM, Sistemas de producción porcina y Subproductos agroindustriales.

Introduction

Population growth along with income levels increases pork consumption, therefore, it is expected that by 2028 per capita consumption will increase; where developing countries will raise their production by 7. 4 percentage points while developed nations only in 2 points despite the fact that China, United States and Brazil are the largest producers of pigs, the expectations of development of the pork sector point to emerging markets where territories must have the availability of resources and specific conditions to perform this livestock activity (OECD and FAO, 2019) it should be emphasized that pork is the most consumed meat in the entire planet where during the period of April 2020-2021 101.5 million tons were produced (United States Department of Agriculture, 2021).

In Colombia for the year 2021 pork production reported 491,233 tons with a growth of 4.9% compared to 2020, however, in the subject of benefit reported 5,950,113 heads, which meant an increase of 3.8% compared to 2020, this production system continues with the growth trend of 8.49 on average since the decade of 2010 (Porkcolombia, 2021). The state of Antioquia is the largest producer with 37.9%, with 24,200 farms with a total of 2,256,460 pigs, followed by Valle del Cauca with a participation of 9.3%% where 3,024 livestock units house 550,756 head; these two states concentrate 47.2% of total production. In relation to demand, 79% was supplied by domestic production, decreasing by 7 percentage points with respect to 2020 (Porkcolombia, 2021). Of the 208,828 farms, 81.2% are backyard farms (ICA, 2021). 76.9% of total swine production takes place in technified farms and the remaining 39.1% are backyard animals.

Although pork production is increasing, it is not enough to meet the demand; in 2010 the share of imports was 10.4%, by 2020 it reached 20.6%; this is due to the Free Trade Agreements (FTA) with Chile, Canada and the United States, the largest supplier country (Ministry of

Agriculture and Rural Development, 2020). Per capita consumption in Colombia for 2019 was 11.2 g/inhabitant (Fajardo López, 2020). For 2019 in Colombia, swine production was 2.82 trillion pesos, contributing 4% share of agricultural GDP and 17% of livestock GDP, generating approximately 150. While it is true that the results reveal an increased consumption of meat, one of the factors that worries producers is the feeding of these animals, where the structure of production costs, the highest cost is reflected in the concentrates that for the year 2019 the approximate consumption reached 1,200,000 tons, of which 619 thousand were of corn and 350 thousand of soybeans (MADR, 2020).

The state of Caquetá reports for 2021 a total of 46,711 pigs in technical and backyard production, developed in 766 commercial and technical farms and 2,120 backyard farms (ICA, 2021). The behavior of this production system has been decreasing, the highest peak was reached in 2019 with 65,572 units, in 2020 it reached 54,029 units, which meant 40% and 17% less respectively. The municipalities prioritized in this research are Albania, Cartagena del Chaira, El Doncello, Puerto Rico and San Vicente del Caguán which present a participation of 65% of the total production (ICA, 2021). Meat consumption per capita is 10.3 kilo for 2018, requiring 5,174,823 kilos of meat equivalent to 14,178 animals per month and 187 units/day to guarantee supply. The receiving municipality with the highest demand for meat is Florencia its capital that requires the daily slaughter of 69 pigs to cover consumption/day, San Vicente del Caguán 27 units consumption/day, followed by the municipalities of Puerto Rico and Cartagena del Chaira that demand 13 units consumption/day (INVIMA, 2019).

The purpose of this research was to characterize swine production in the state of Caquetá based on the knowledge of the use and exploitation of non-timber forest resources (NTFR) and agro-industrial by-products produced in the state for the development of nutritional protocols for swine feeding that contribute to the reduction of production costs and increase production parameters.

Theoretical framework

Conventional swine production systems are based on commercial diets elaborated from corn and sorghum; these are the main source of energy for the nutritional requirements of the species; on the other hand, soybean meal, oilseed cakes, fish meal, meat and/or bone meal provide protein, vitamins, minerals and additives (Acosta et al., 2006; Campabadal, 2009) , it is worth mentioning that concentrated feeds represent about 80% of the cost structure impacting on the low profitability and productivities of livestock farms; with the growth in meat consumption and the challenge of achieving higher production, the need to import a greater amount of corn and sorghum has been generated, which guarantees the production of balanced feed that has been increasing since 2016 where consumption was 15.5% for swine production and in which the largest producer of these raw materials is the United States (López, 2016). Therefore, to encourage the growth and competitiveness of production systems, the generation of nutritional protocols using various raw materials such as RNMB and agro-industrial by-products is required, complying with the nutritional requirements of pigs against the productive parameters necessary to convert these farms into sustainable agricultural systems (Hernández-Bautista et al., 2009, Calle 2016).

Non-Timber Forest Resources (NTFR)

NTFR are considered as the goods or products of plant and animal origin obtained from the forest (Vargas et al., 1997); they are composed of all biological materials such as fruits, ornamental and medicinal plants, among others, other than wood (Beer and McDermott, 1989). These

resources include all tangible products, except standing timber, logs, firewood and charcoal, which play a decisive role in the daily life and well-being of local communities, due to the inputs they provide such as food, fodder, fertilizer, energy, fiber, medicine, oil, resin, rubber and construction material, among others. They are also important as raw materials in numerous processing industries and are sometimes used as commodities. They also contribute to biodiversity conservation and other environmental objectives (FAO, 1996). Likewise, the production and use of NTFR contribute to food, housing and health needs, while allowing the generation of income, which for 2014 amounted to approximately 88 billion USD, originating mostly from NTFR of plant origin (77 billion USD), NTFR of animal origin contributed (10.5 billion USD) and the collection of medicinal plants reached (700 million USD), which is 1/6th of timber forest production (FAO, 2014).

The valuation and use of NTFR are viable strategies that allow the sustainable management of forest resources and crops; however, from an economic perspective, there is a lack of specific regulations that allow a better use of these resources (Aguirre and Aguirre, 2021), it is worth mentioning that native communities traditionally use these resources for food, beverages, human medicine and rituals (Songor et al., 2021). In Colombia, NTFRs have not been used despite their high potential in several areas, including some cultivated resources. An example of this diversity was reported by Ábalos and Romero (2001), who pointed out that several of these species are used as rubber, natural latex, essential oils, spices, condiments, food, multipurpose medicine, feed for stabled and grazing animals and pigs. For its part, the Amazon region is characterized by its great natural wealth of native species of flora, therefore, its Non-Timber Forest Resources (NTFR) are used by indigenous communities as medicine, food, materials for the construction of houses, canoes, dyes, ingredients, among others (Tapia and Reyes, 2008); providing protection to communities against uncertainties arising from climatic conditions that may affect the prevention of resources for current populations and future generations (Gutiérrez et al., 2017).

Among the NTFRs, palms are an alternative with great potential as a source of energy base in the tropics, which can increase animal production, as they are the major producers of fatty acids. One of these is the *Oenocarpus bataua* (milpesos palm), which provides high levels of protein superior to the sources currently used in human food (Durán, 1999; de la Llata et al., 2001). The study on the use of palms, including *Mauritia flexousa* or Canangucha and *Oenocarpus bataua*, indicates that they are a highly variable of NTFR, with a wide range of uses ranging from construction, manufacture of handicrafts and utensils; they are also used in human and animal food; however, they indicate that despite the gaps in the information, they are a potential resource to ensure food security and sustainable development in the Colombian Amazon (Mesa & Galeano, 2013). Therefore, the use of these varieties of palms as NTFRs becomes a valuable resource not only because of the high nutritional quality oil content of the fruit, but also because their use contributes to the conservation and sustainable use of the forest, as traditionally done by native communities with few economic resources that need to seek sources of income in their subsistence family farming model (Lavado & Duran, 2015; Ocampo et al., 2013). It should be emphasized that Silva et al. (2020) found that the supply of feed with *Oenocarpus bataua* palm oils as energy supplementation on the lipid profile of seminal plasma and sperm membrane; seminal plasma in buffaloes increased in the expression of saturated and unsaturated fatty acids in the sperm membrane and improved important semen parameters such as progressive motility, sperm viability and mitochondrial potential of cryopreserved semen that are directly related to fertilization capacity. In summary, the consumption of palm oil in animal feed reduces the health risk by improving the oxidation processes of the species (Edem, 2002).

On the other hand, *piptocoma discolor* has been used in different livestock agroforestry arrangements. In a study carried out, the effect of three different levels of tree cover on milk production was evaluated in dual-purpose livestock systems in the humid tropics of the Colombian Amazon region, the results indicated that *piptocoma discolor* was the tree species with the highest relative frequency percentage in the three cover levels with 59.76% for the high cover level, 45.16% for the medium cover level and 28.89% for the low cover level (Alvarez et al., 2021). Likewise, studies on *Cratylia argéntea* as NTFR show that it has a high forage potential due to its protein supplement content, which alleviates the protein deficiencies of ruminants that are common in the dry season due to its high protein breakdown capacity in the rumen, the study suggests that the positive effect of this forage as a supplement in cutting and hauling systems will be better if it is combined with an energy-rich source such as sugarcane (Argel and Lascano, 1998), it is thus that the use of perennial forage woody where the nutritional quality is highlighted mainly by the contribution of protein and high levels of digestibility, which allows establishing its potentiality in the use for animal feed (Enciso et al. ,2018).

Agro-industrial by-products

Agro-industrial by-products are used in animal feed because of their nutritional value (protein and/or energy, etc.).); these are considered as a strategy for environmental conservation because they are potentially polluting, as is the case of palm kernel cake, used as a non-conventional food source available in oil palm (Elaeis guineensis) processing zones, which is obtained by harvesting the palm bunch, composed of fruit (61%), which is mechanically processed to obtain oil, subtracting the palm kernel, which corresponds to 35% of the initial bunch (Vargas and Zumbado 2003). Palm kernel meal is being used as an alternative for the palm oil agroindustry, making it possible to include it in swine feed due to its good nutritional content, comparable to that of corn and soybean, as well as its cost (Jang et al., 2020).

On the other hand, the inclusion of cocoa husk (Theobroma Cacao) has a positive impact on productive parameters, improving the cost-benefit ratio, since it contains pH values of 8.65%, protein of 14.42% and fiber of 14.42%; protein of 14.42% and fiber of 6.2% (López, 2013), presenting itself as an alternative for the reduction of swine feed costs by supplying up to 10% of this by-product in the balanced diet, influencing the improvement of the profitability of supplies because it alleviates the cost of commercial diets, generating greater profits for producers, contributing positively to productive and nutritional behavior (Loor 2021; Pedroza, 2021). It should be added that the more concentrated feed is used, the lower the profitability, which recommends a better management of the various by-products and agro-industrial residues with great potential such as coffee, oil palm, sugar cane, cocoa, among others, however, cocoa is an important crop in Colombia where the shell and husk reports a crude protein up to 23% and 41% corresponding to the fraction of protein that degrades rapidly in the rumen and have been valued as "supplement in diets for pigs with an inclusion rate higher than 10%.

Methodology

In order to achieve the stated objective, based on the postulates of Hernández Sampieri et al. (2014) a non-experimental methodological design of exploratory and descriptive - transactional scope with mixed approach was implemented through the application of a semi-structured survey to 44 swine units located in five municipalities of the state of Caquetá.

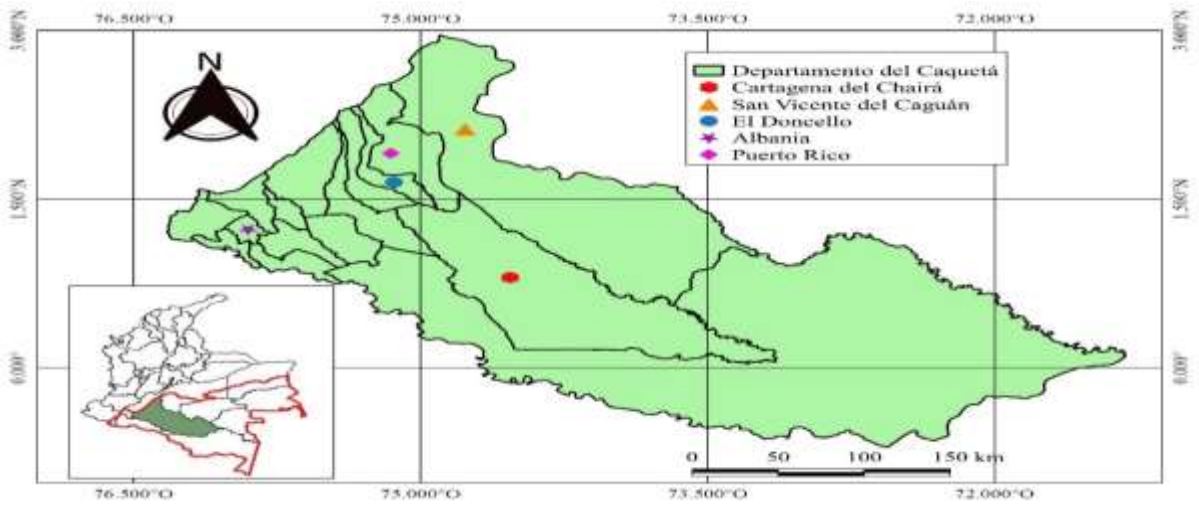

Figure 1. Map of selected municipalities in the state of Caquetá. Source: own elaboration in R-studio (2021).

It should be added that the following selection criteria were taken into account for the selection of the production units to which the collection instruments were applied: (i) the productive units must have a swine production system; (ii) the farms must allocate at least one hectare of land use of forest, *Cananguchal* or have *Cratylia argentea* cultivation or *Piptocoma discolor* trees or make use of palm kernel cake and cacota. The data collected during this phase were analyzed using the Statistical Package for Social Sciences - SPSS software through a multivariate approach of the socioeconomic constructs that affect the use of NTFR and agro-industrial by-products in animal feed. Likewise, a bibliometric analysis was carried out in various databases such as Scopus, Web of science, PubMed, Scielo, Google scholar and Dimensions based on the descriptors of NTFR and Agroindustrial By-products (independent variable) in swine production systems (dependent variable), allowing the identification of research trends in relation to the subject in question.

Table 1. Topics and search terms in the databases.

Topics	Search term
Non Timber Forest Resources	(("SWINE" OR "PIG" OR "SWINE" OR "PIG" OR "SUS SCROFA DOMESTICUS") AND ("ANIMAL FEED" OR "ANIMAL NUTRITION" OR "USE" OR "UTILIZATION") AND ("MAURITIA FLEXUOSA" OR "OENOCARPUS BATAUA" OR "PIPTOCOMA DISCOLOR" OR "CRATYLIA ARGENTEA" OR "NON-TIMBER RESOURCES" OR "NON-TIMBER FOREST PRODUCTS" OR "NWFPS" OR "NON-TIMBER FOREST PRODUCTS" OR "NTFPS"))
Agroindustrial Byproducts	(("PORCINE" OR "PORK" OR "SWINE" OR "SUS SCROFA DOMESTICUS") AND ("ANIMAL FEEDING" OR "ANIMAL FEED" OR "ANIMAL NUTRITION" OR "USE") AND ("PALMISTE" OR "PALMISTE CAKE" OR "AFRICAN PALM CAKE" OR "AFRICAN PALM FLOUR" OR "ELAEIS GUINEENSIS FLOUR" OR "ELAEIS GUINEENSIS CAKE" OR "COCOA SHELL" OR "CACOTA" OR " COCOA" OR "COCOA

	PODS" OR "COCOA COB" OR "AGROINDUSTRIAL BYPRODUCT"))

Note: The table shows the concepts searched, where the first topic yielded about 263 scientific documents in Scopus and the second term is limited to publications between 2007 and the present, where 2,272 publications were found. Source: own elaboration (2022).

Findings

Bibliometric analysis

The bibliometric analysis showed the following results for the constructs investigated in the various databases through the application of Boolean formulas constructed from the descriptors of the NTFR and agro-industrial by-products research:

Non-Timber Forest Resources (NTFR).

The growing importance of food security on the planet has led society to consider non-conventional sources of consumption to supplement the nutritional demand of communities and their animal production systems, which is why they have opted for the use of the ecological resources of their territories. Hence, Pierce & Laird (2003) refer that the trade of NTFR should be regulated from a set of comprehensive standards that favor the socioeconomic development of the communities (Sampaio et al., 2012; Endamana et al., 2016; Sakai et al., 2016) contributing to the sustainable use of resources through strategies that allow the conservation of biodiversity in the territories (Gavin & Anderson, 2007); consequently, the need is created to formulate bioeconomic models that allow the achievement of this objective (Sirén & Parvinen, 2015). Simultaneously, Makkar et al. (2007) emphasizes the phytochemical properties of various plants that have great potentials for animal production systems contributing to the construction of sustainable agricultural organizations that seek to mitigate the damages produced by their economic activity (Rivera et al., 2016). It should be emphasized that there are precedents of researches that allude to the intake of these NTFR in the feeding of pigs with forage species (Sarria & Martens, 2013).

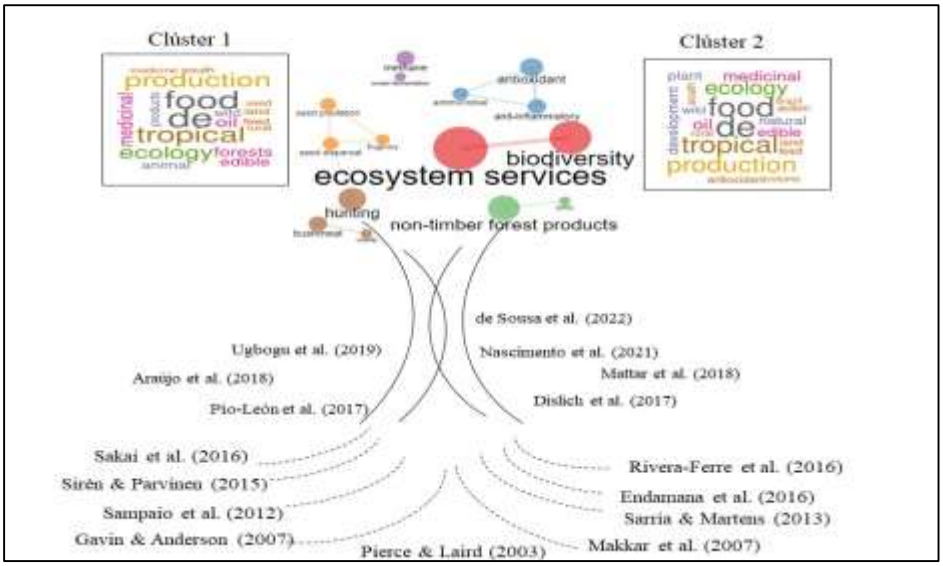

Figure 2. Tree of the utilization of NTFR in animal feed.

In turn, Figure 2 shows that the studies conducted since 2017 have led to the recognition of various species of flora (NTFR) under their uses from circular economy models (Pío et al., 2017) and use as a resource with food potential as is the case of oils derived from the fruits of wild palms (Dislich et al., 2017; Araújo et al., 2018; Nascimento et al., 2021; de Sousa et al., 2022) and forage shrubs (Mattar et al., 2018); this with the objective of using different raw materials from soybean, corn and sorghum monocultures that are the basis of commercial diets, thus reducing the impacts of production systems by taking advantage of the potential of the forest (Ugbogu et al., 2019).

It should be added that about 97% of the scientific studies on this issue are in English followed by 2% in Spanish and 1% in Portuguese. The largest number of research papers conducted worldwide related to the use of NTFR in animal feed are conducted in Brazil, the United States and China, it is necessary to emphasize that Brazil having the greatest biodiversity in the world has the advantage of studying these products by having 20% of the species distributed in its biomes (Monteiro et al., 2021); another important feature about these countries belongs to the accelerated expansion of disruptive technologies questions the models of production and services built by the industry in the 20th century (Arbix et al., 2017), this generates changes in the behavior of consumer markets and points to profound economic and social changes.

As evidenced in Figure 3, the most relevant documents by the number of citations whose topic is related to the use of NTFR in animal feed, where research focused on biotechnology, animal feed, edible plants and cosmetic services; this originated to the fact that there is currently a growing demand for more selective and cleaner processes coupled in an environmentally friendly production (Sajjadi, 2018).

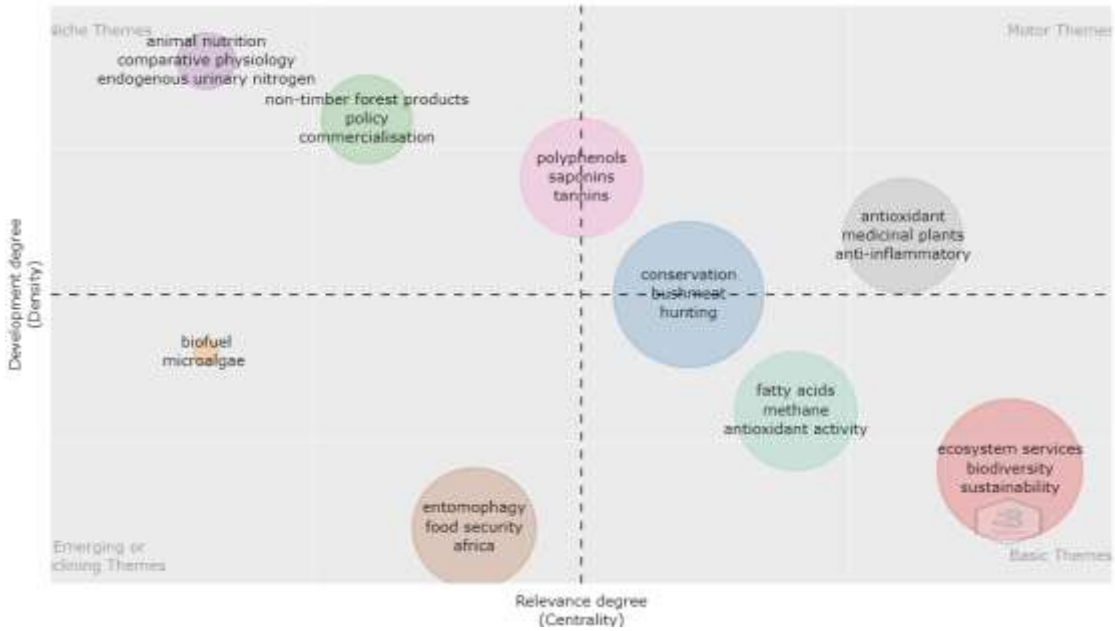

Figure 3. Trend of the conceptual structure of the scientific production of NTFR in animal nutrition.

On the other hand, the main research topics related to NTFR are antioxidants, medicinal plants and anti-inflammatory processes; these topics are derived from the need to understand these natural resources in order to take advantage of their potential for the common good of society based on the analysis of their physicochemical properties (Figure 3); it should be noted that animal nutrition and the commercialization of NTFR have been little studied due to the fact that studies

are currently in the diagnostic phase of the resources. Likewise, it should be noted that topics related to conservation, ecosystem services and the sustainability of NTFR have been cross-cutting topics in various research studies (Córdoba et al., 2019; FAO, 2011).

Agro-industrial by-products (AIBP)

Today's society faces the challenge of generating clean processes by applying concepts such as the circular economy that seeks to make use of waste during the transformation phase of raw materials; therefore, agroindustrial by-products such as cocoa husks, being a product rich in fiber, have the potential to be a non-conventional source used in nutritional protocols for productions such as pigs (Lecumberri et al, 2007; Oddoye et al., 2010; Magistrelli et al., 2012; Adamafio, 2013; Magistrelli et al., 2016; Rojo et al., 2020). Simultaneously, studies focusing on developing feeds from conventional and unconventional HS (Sol et al., 2016; Sol et al., 2017) have highlighted their high potential in the incorporation of diets such as swine due to their high energy percentage and chemical composition that favors in vitro digestibility; which favors meat characteristics, fatty acid profile and lipid oxidation (de Evan et al., 2020).

On the other hand, Figure 4 shows that research developed since 2021 has determined the search for agro-industrial by-products that are easily available in the territories and that seek to reduce economic costs in animal feed (Babatunde et al., 2021); it should be emphasized that palm kernel cake has been proposed as an alternative raw material to reduce costs in animal feed in order to eliminate dependence on imports of concentrated feed (Azizi et al., 2021). Currently, there are several perspectives that point to the utilization of HS as feeds for swine productions that can improve growth performance, meat quality of piglets and growing pigs, and improve production yield, milk and sow quality without ignoring the anti-nutritional ingredients that these products present (Yang et al., 2021; Galassi et al., 2021; Solano-Aguilar et al., 2021).

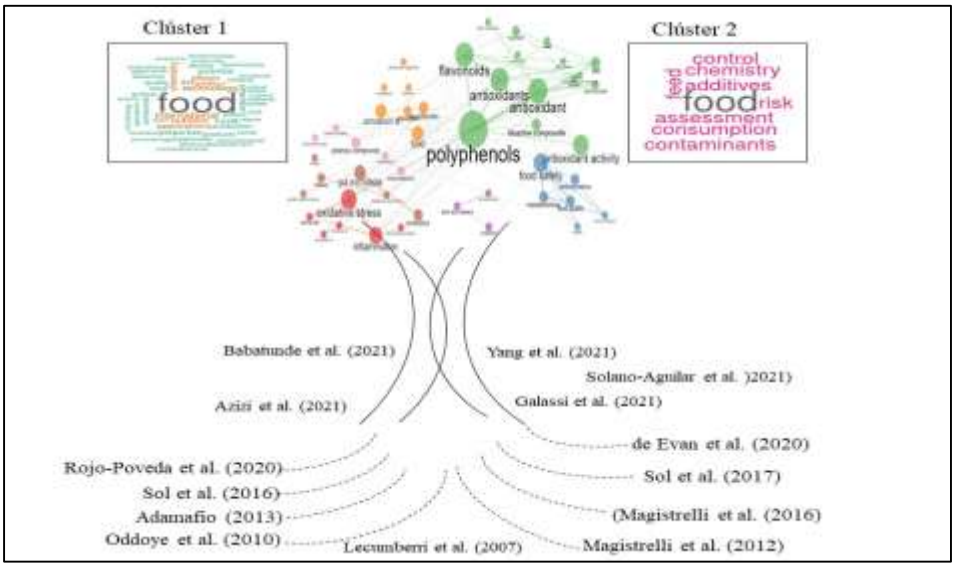

Figure 4. Tree of the use of agro-industrial by-products in animal feed.

The largest number of research papers conducted worldwide related to the use of agroindustrial by-products in swine feed between 2007 and 2022, are conducted in China, United States, Spain, Brazil, India and Italy; where 98% of the scientific papers are published in English, however, China being a world power has a strategic agenda to ensure food security in its territory

as it is a flashpoint for its economy where thanks to the constant intervention of the state allows controlling and stabilizing food prices (Trápaga, 2017). On the other hand, the greatest contributions to the knowledge of the use and exploitation of agroindustrial resources in swine feed are made by countries such as China and Brazil, which, thanks to their great industrial potential, have the technology for the development of this research, without ignoring their vision as export and foreign investment markets (Paulino, 2019).

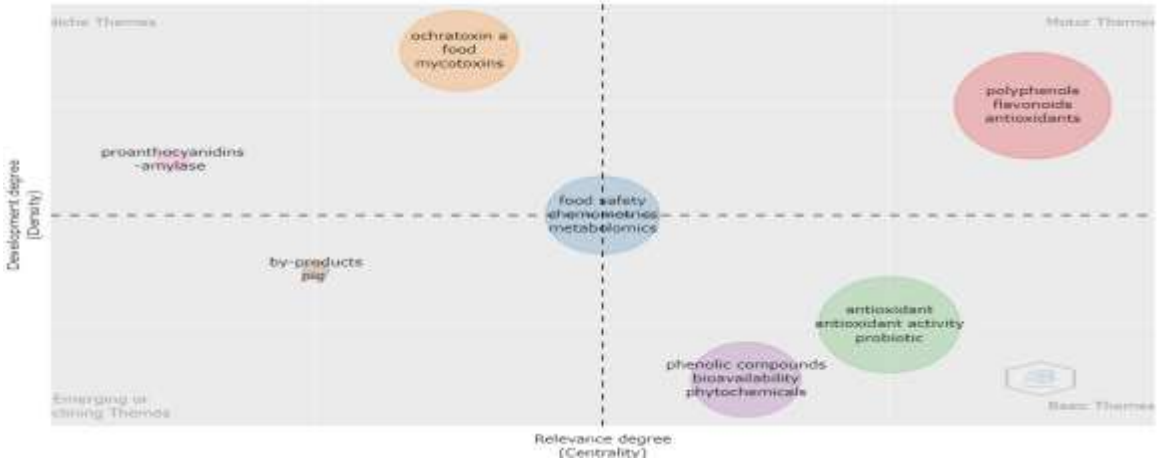

Figure 5. Trend of the conceptual structure of the scientific production of agro-industrial by-products in swine feed.

As it is evidenced in Figure 5, the consolidated topics around the use of AIBP in animal feed revolve around the concepts of polyphenols, flavonoids and antioxidants that are based on the understanding of the potential of these resources for the elaboration of balanced diets that contract benefits for the species as dietary components with a substantial impact on health (Williamson, 2018); it is highlighted that the studies on pig feeding with these by-products are an emerging topic that seeks to generate a disjunction in the nutritional protocols of conventional swine systems. In relation to the transversal themes, the topics are related to the study of probiotics, phenolic compounds, bioavailability and phytochemicals; reflecting the depth in the understanding of the substances that can influence the use of their potentialities. As opposed to the conceptual structure of the topics with little linkage based on the study of ochratoxin, food, mycotoxins, proanthocyanidins and amylase

Use of Non-Timber Forest Resources (RNMB) and Agro-industrial By-products (SA) in swine production systems in the state of Caquetá

With regard to the characterization of swine production systems in the use and exploitation of HS and NTFPs in animal feed in the municipalities of Cartagena del Chaira, Albania, San Vicente del Caguán, El Doncello and Puerto Rico, the following results were found:

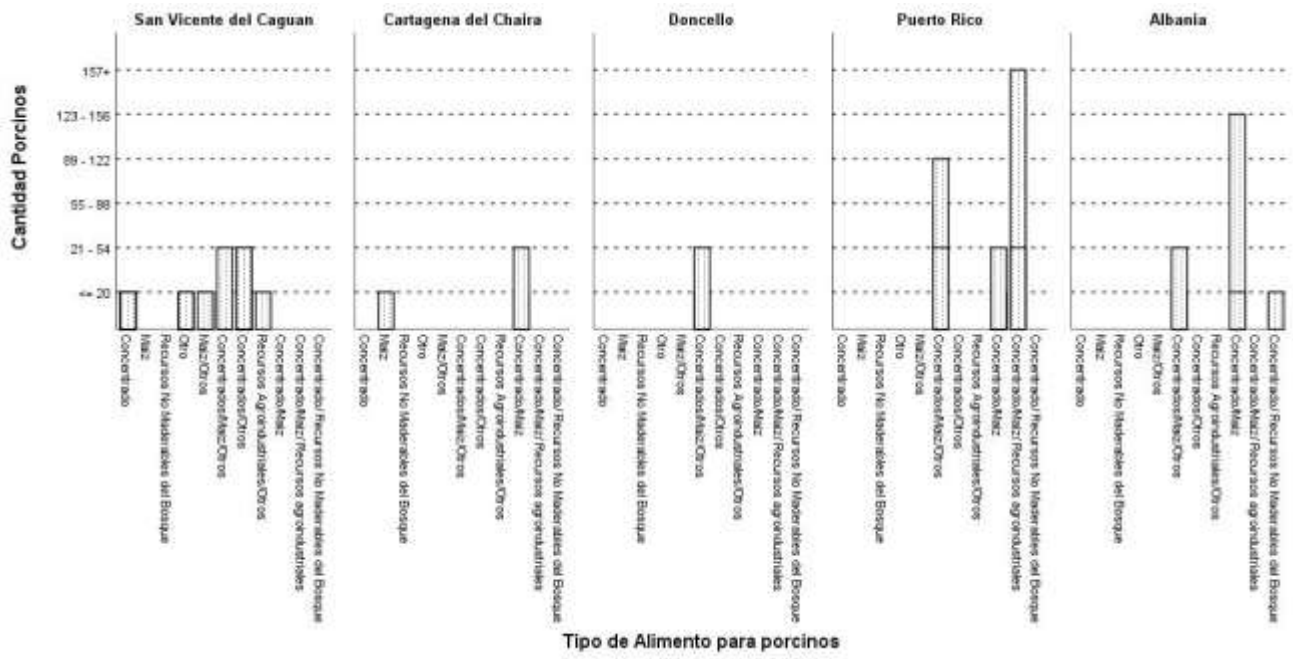

Figure 6. Type of feed used in swine production.

The use and utilization of NTFR and AIBP in swine feed represent a paradigm shift in production systems due to the high dependence on nutritional protocols based on the intake of commercial diets (Urrego et al., 2011), but in the case of the municipality of Puerto Rico they associate it with agro-industrial by-products and corn, as well as producers in Albania and Cartagena del Chaira sustain with concentrate feed and corn (Figure 4); likewise, swine production systems in the municipality of San Vicente del Caguán use by-products because it allows improving productive and economic parameters decreasing the costs incurred by productions (Benítez et al., 2015).

In the feeding of pigs in the state of Caquetá, it was found that 93% of producers do not use NTFR in swine feed, only 2% use Canangucha (Figure 7A). In the use of agro-industrial by-products, it was found that producers use a large proportion (52%) of other by-products, especially milk whey and approximately 7% use palm kernel (Figure 7B). In general terms, there is a use of alternatives to replace traditional foods, because producers have identified sources rich in protein and energy that are found in the region and have a lower cost. It should be noted that approximately 37% of the producers surveyed were unaware of the potential of agro-industrial by-products in the implementation of diets for pigs.

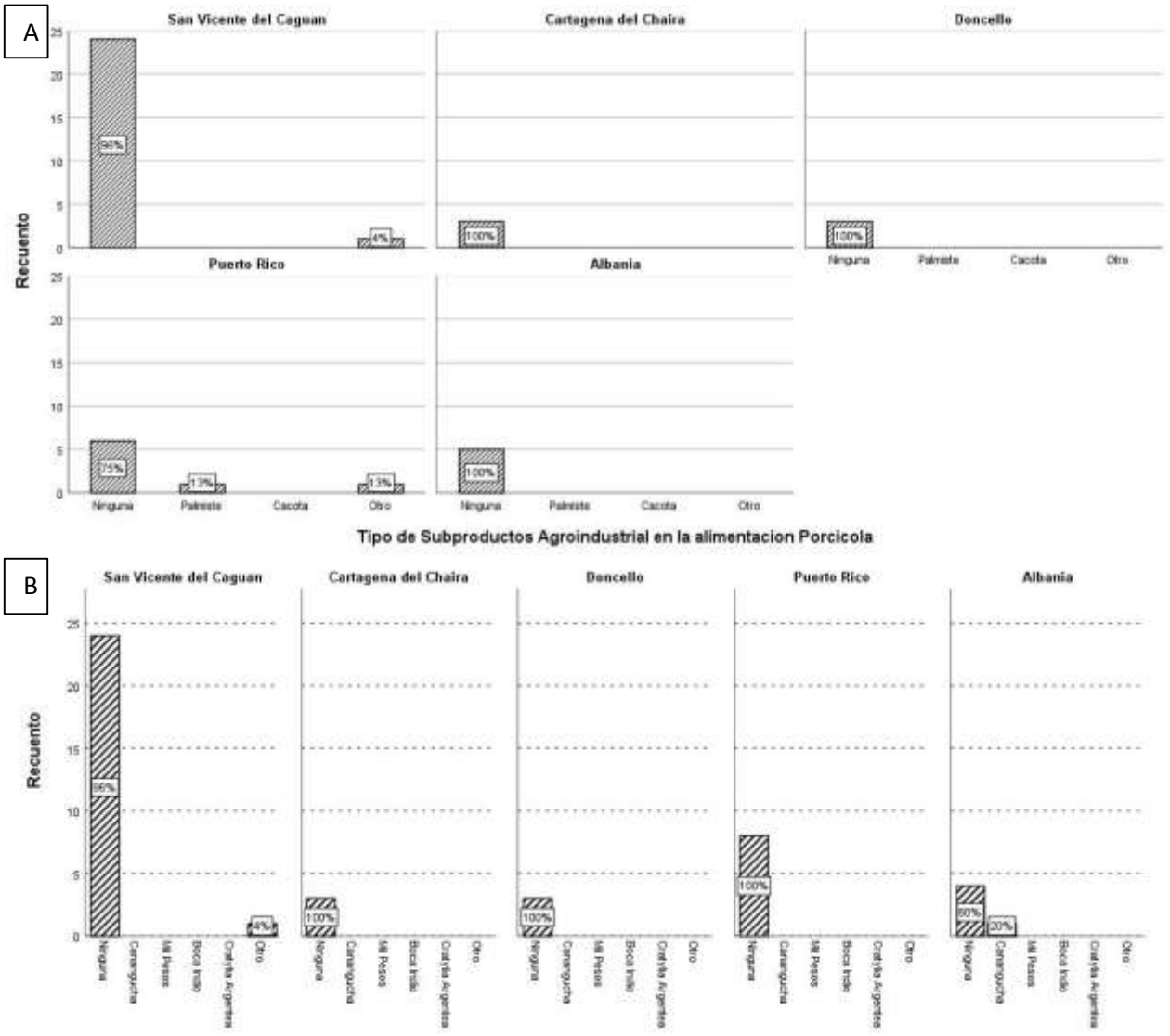

Figure 7. Use of NTFR and agro-industrial by-products in swine feed.

It is necessary to emphasize that the use of NTFR in animal feed such as *Mauritia flexousa* oil increases the energy consistency of the animals (Diogénes et al., 2020), likewise, forage species such as *Piptocoma discolor* showed that it helps to maintain stable cholesterol levels and improve glucose levels (Riascos et al., 2021); and in the use of by-products such as cocoa (*Theobroma cacao*), which represents approximately 90% of the weight of the fruit (Abarca et al., 2010; Saval, 2012), it has a high fiber content and nitrogen free extract (NFE) content, which has a positive impact on digestibility in its intake (Yoplac et al., 2021).

Regarding pig facilities, most of the production systems do not have infrastructure division because this sector is generally developed in open fields (backyard) while the few that are implemented in confinement are built in cement, brick and wood (Figure 8 A); As evidenced by the livestock census where about 81% of the pig units in the national territory are backyard (ICA, 2021), which means that they are not productive and do not have a great impact on the economy of the producers because they do not promote social development, making economic growth and development of large-scale commercial activity impossible because the little production that is

developed is for self-consumption (Figure 8 B). It is worth mentioning that these factors do not contribute to the development of a highly competitive environment for the socioeconomic development of this sector in the state, reflecting the need to encourage this activity because the state has an unsatisfied demand, which is why domestic consumption is surpassed by the total supply of pig slaughter.

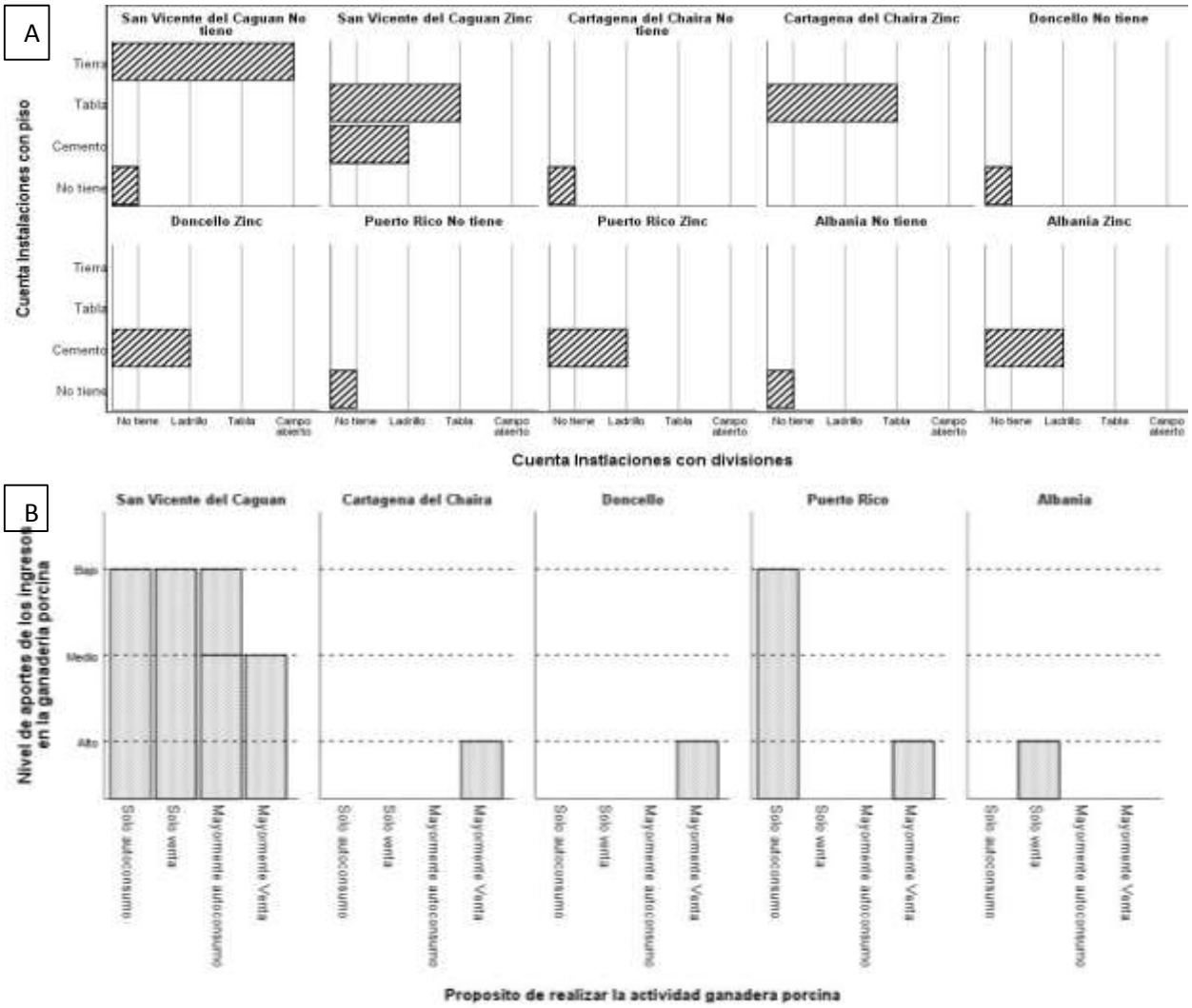

Figure 8. Facilities destined to production systems and level of participation in swine income.

On the other hand, the commercialization of the products is largely carried out by intermediaries that in some occasions can be represented by community action boards and on the other hand the committees, as shown in Figure 9, municipalities such as Albania 50%, Doncello 21% and Cartagena del Chaira 29% state that they commercialize their products through an intermediary such as the Communial Action Boards; which reflects the increase in the price of pork due to the value added on the product by each participant, it is worth mentioning that this value ends up being assumed by the final consumer.

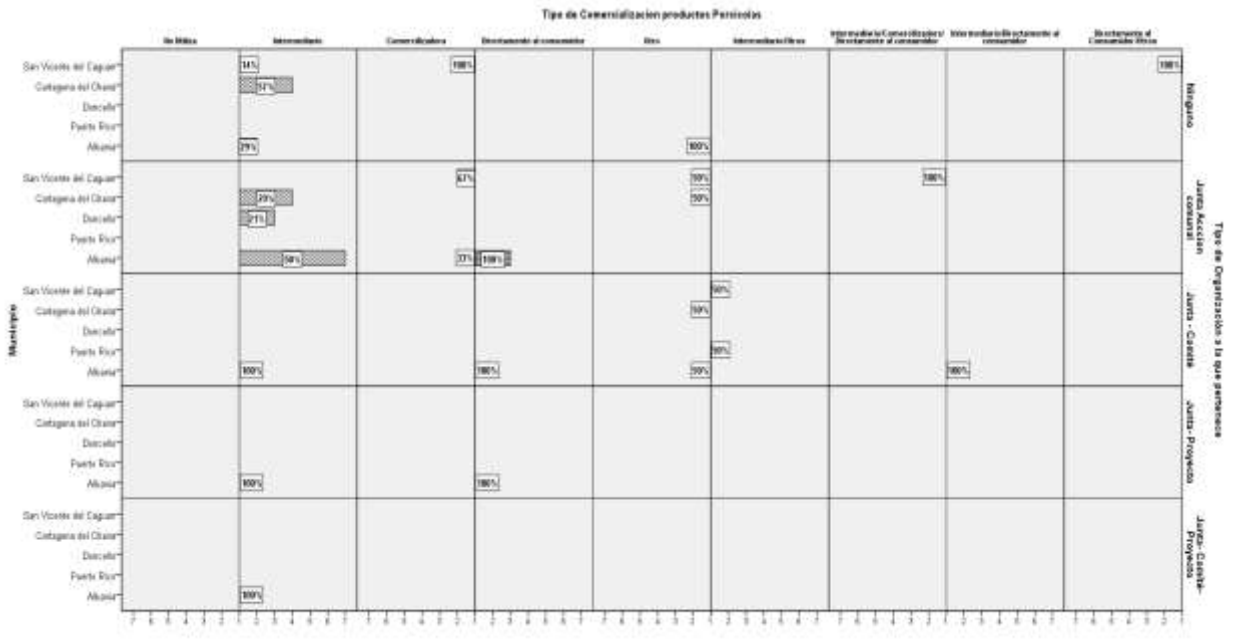

Figure 9. Type of marketing of pigs.

Although it is true that per capita consumption has increased in recent years, in the state of Caquetá, there is only one processing plant with the conditions required by INVIMA for the slaughter of pigs, which is offered by the company COFEMA S.A., a plant that has the installed capacity to slaughter 200 head of pigs (COFEMA, 2019). It should be added that in 2020, the state of Caquetá presented a critical situation due to the illegal slaughter of pigs, which affected the processing plant, together with the requirements of INVIMA that forced the company to take decisions to avoid closure, due to the consequences it entails, which generates the continuity of the problem of illegality that is worrying because it does not guarantee that this protein reaches the final consumer under the conditions established in the current regulations (Contexto ganadero, 2020). On the other hand, there is not associative structure to establish a direct marketing channel between pork producers and the institution providing the slaughter service.

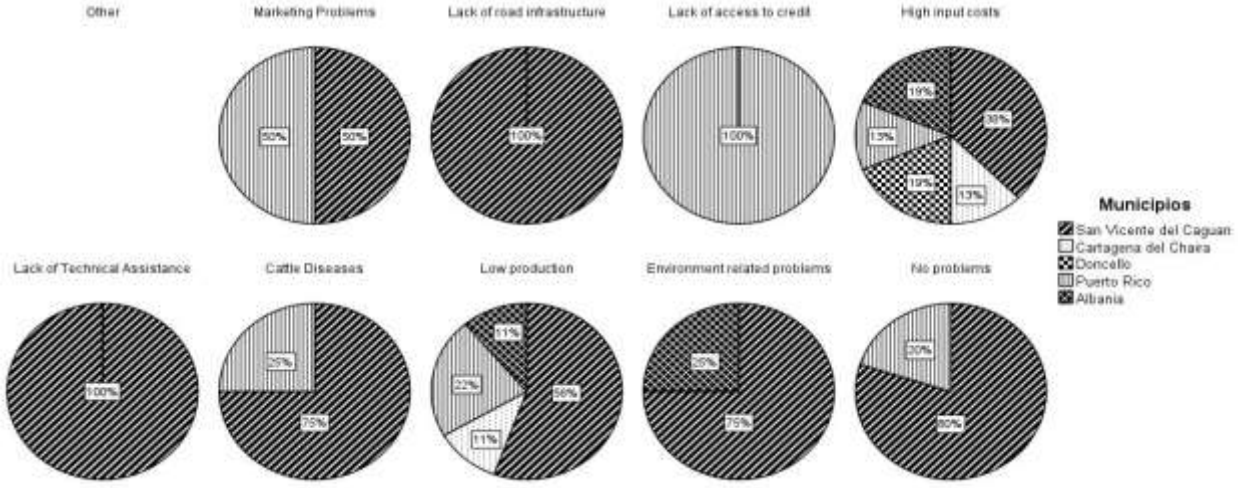

Figure 10. Main problems of swine units.

In turn, the main problem pointed out by the producers was the high cost of inputs, which is directly reflected in the high cost of swine feed, since this is an important item in the cost structure of the production systems, affecting the profitability of the production systems. It should be noted that the second problem affecting this sector is low productivity due to the low level of technification of the production units, which in many cases do not have the physical or organizational infrastructure that would allow them to intensively scale production and access the benefits and incentives provided by the state.

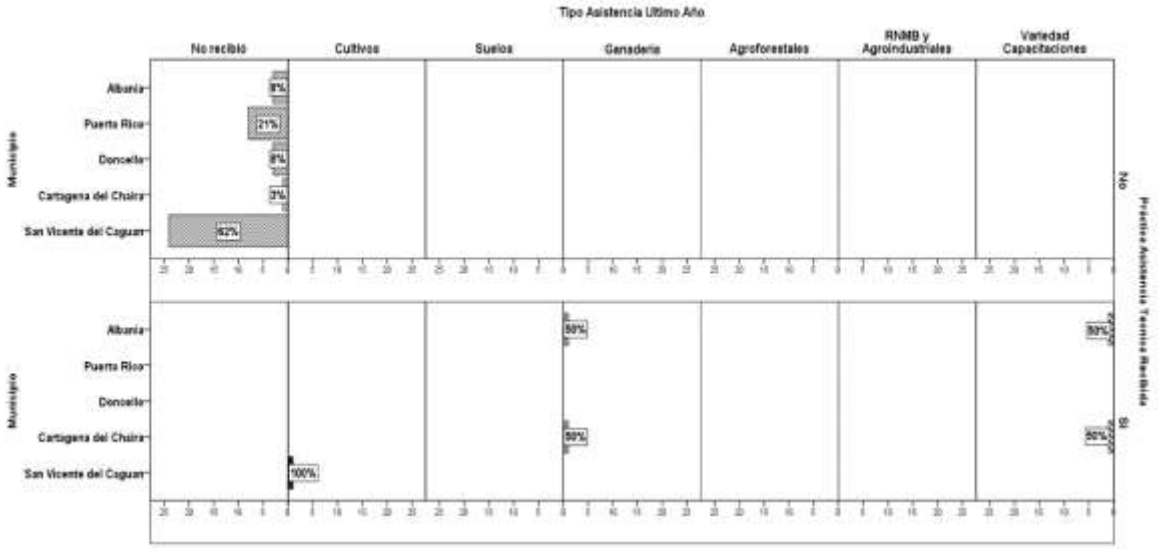

Figure 11. Type of technical assistance in swine units.

Simultaneously, these pig farmers have not received any type of technical assistance, which limits the processes of technification and good practices in the management of their production systems, although the municipalities of Albania, Cartagena del Chaira and San Vicente del Caguán have received technical assistance focused on crops, livestock, among others; This shows the disarticulation of public policies in agricultural technical assistance due to the fact that the reality of producers who demand more state participation in the processes of production technification is unknown. Consequently, these producers are unaware of the new realities of their economic activity in terms of nutritional alternatives that can help reduce production costs with the use of NTFRs from their own territory, and are also unaware of the various incentive programs and economic benefits that assist the socioeconomic development of these systems, which are generally subsistence systems.

Conclusions

Currently, producers must explore various production strategies that have an impact on good nutritional quality and improve pig management practices, ensuring animal welfare during the production chain; Therefore, in view of the growing demand for meat caused by the increase in per capita consumption, production systems must aim to improve productivity levels to meet national demand, based on strategies to promote and strengthen the sector, taking advantage of the potential of biodiversity in the territories through innovation.

Regarding the challenges posed by food security in swine production systems, the potential of NTFR and agro-industrial by-products to meet the demand for animal protein that can affect their productivity and competitiveness is highlighted, considering that proper forest management contributes to the sustainability of the units, as well as the use of agro-industrial resources that contribute basic elements to the nutritional requirements of the species.

Pig production systems in the selected municipalities in the department of Caquetá showed that 90% of the production units are backyard units, reflecting the low level of technification, which leads to aggravate the problems of the sector. It should be noted that only 7% of the producers surveyed use or take advantage of the NTFR and agro-industrial by-products, highlighting the lack of knowledge of their potential for animal intake, which means that they are not the main source of income because they develop other activities such as cattle raising. At the same time, another problem afflicting this sector is the lack of tertiary roads, technified infrastructure, marketing chains and lack of technical assistance, which leads to low productivity levels in swine systems, affecting their cost structure and profitability, which affects the socioeconomic development of producers. Therefore, the use of by-products (*Cacota* and *Palmiste*) and RNMB (*Cratylia, Bocaindio, Palma de Milpesos and Canangucha)* are a viable alternative for reducing the cost structure of the organizations, which positively affects profitability due to the reduction in the purchase of concentrated feed.

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