

METHODOLOGY FOR THE ARTISANAL PRODUCTION OF BOKASHI IN A CASHEW NUT CROP: A CASE STUDY

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Abstract:

The research focuses on the need to develop a methodology for composting applied to the cultivation of *Anacardium occidentale* (cashew), to optimize and provide an alternative in times of input shortages and high costs. This research arises from the need to find sustainable and economical solutions for farmers. The research was carried out in an exploratory and diagnostic manner. Farmers were involved in building the bokashi on the Namasté farm, using raw materials from the productive unit. A statistical inference analysis was performed through linear regression and correlation tests. The dependent variables temperature and pH were analyzed. It was established that the temperature affects the composting phases, allowing the proposed method to be proven and useful. The efficiency of the bokashi-type composting was found for the cultivation of *A. occidentale* (cashew). The dependent variables temperature and pH were analyzed. The agricultural production was optimized through the use of bokashi-type composting. The objective of proposing a methodology for composting applied to the cultivation of *A. occidentale* (cashew) was achieved. The proposed method can continue to be studied, experimented with, and explored, since it provided optimal results. Bokashi-type composting is a low-cost and easy-to-apply alternative to optimize agricultural production. This research contributes to farmer's sustainability and economy.

Keywords: *Anacardium Occidentale*, Soil Quality, Farmers; Rural Communities, Organic Fertilizers, Organic Fraction.

INTRODUCTION

The global environmental and social crisis has generated a critical point in raw materials and agricultural production, affecting the agricultural sector in Colombia (Ramos Agüero y Terry Alfonso, 2014). Global warming and the global crisis have led to an increase in the prices of chemical fertilizers, complicating the management of raw materials for soil fertilization and agricultural production. However, farmers have an alternative option to agrochemicals: developing products with organic fertilizers. This innovation allows for decision-making in the face of the supply crisis (Ortiz Gutiérrez et al., 2022).

In the Colombian context, this shortage has given rise to various alternatives among farmers, who have sought to generate new mechanisms for low-cost fertilization, using inputs and materials produced by the same soil or productive unit. It is from this that, in the municipality of Baranoa, cashew (*A. occidentale*) producers have had to face the scarcity of agrochemicals and have partially transitioned to generating agroecological processes for the sustainability of the crop. This crop represented 87 hectares and 677 tons/year in the municipality in 2020 (Minagricultura, 2020). This research is important because it explores and proposes a methodology for developing composting alternatives through bokashi-type compost, to be applied as an amendment during agrochemical



shortages in the cultivation of *A. occidentale*. This poses a challenge for agricultural production and rural development, as it allows for reconversion and strategy in response to market needs for obtaining raw materials. This research proposes a practical solution to the crisis and a way to transition towards sustainable agroecological processes, through the use of organic composts as an alternative to agrochemicals.

Based on the above, the objective of this research was to propose an artisanal production methodology for bokashi for the cultivation of cashew (*A. occidentale*) at a low cost for productive units in the municipality of Baranoa (Atlántico, Colombia).

Theoretical Foundation: The importance of organic fertilizer. Producing organic fertilizers, such as bokashi, using different organic materials, is an artisanal technique for transforming waste into valuable resources, reducing investment costs, improving soil quality, and increasing crop yields. This technique is accessible to farmers due to its low cost, as the organic materials used, such as manure, compost, and plant material, are rich in macronutrients and micronutrients that benefit soils and crops (Mendivil-Lugo et al., 2020). According to Month, (2023) bokashi-type organic fertilizer is obtained through the fermentation and maturation of plant or animal material. This favors the degradation of organic matter under controlled conditions of temperature, humidity, and pH, contributing to soil improvement through its nutritional content, reducing production costs, and increasing agricultural productivity.

The difference between traditional composting and bokashi lies in the maturation time and the materials used. Traditional composting requires a maturation period of between 2 and 6 months, and is made mainly from a mixture of plant waste and animal manure. Bokashi, on the other hand, has a maturation time of approximately 60 days and uses a mixture of efficient microorganisms that promote fermentation and accelerate the decomposition of organic matter. (Lizarzaburu Aguinaga, Saavedra Pinedo, Bravo Guevara, Benites-Alfaro, & Orrego Cumpa, 2023). The relevance of a methodological proposal. According to Olmedo y Lamprea, (2023), the application of bokashi-type organic fertilizers is relevant for promoting sustainable agriculture. For Hata et al. (2023) These fertilizers are obtained from farm waste, reducing costs, and providing soils with macronutrients such as NPK (Nitrogen, Phosphorus, and Potassium) and micronutrients like Calcium (Ca), Magnesium (Mg), Sulfur (S), Molybdenum, and Carbon (C), improving their physical, chemical, and biological characteristics. This increases soil water retention and aeration, favoring crop growth. By absorbing nutrients through their roots, plants obtain higher yields and better economic returns (Limbongan, 2023).

This contributes to new rural perspectives on the transition that agricultural production must undergo, from replacing agrochemicals with organic fertilizers that contribute to rural development to integrating and participating in community development (Rizal et al., 2022). Organic fertilizer management has become a readily accessible tool, ensuring sustainable production of transitory and perennial crops (Hs et al., 2023). New alternatives for organic fertilizers. Today, agricultural processes are seeking fewer polluting alternatives for soil and new forms of fertilization without the use of agrochemicals. The productive system is making a greater effort to promote the use of organic fertilizers through biodegradable recycled materials and the reuse of organic matter, aiming to reduce organic waste and minimize the use of toxic agrochemicals for human health and the environment (Ruiz-Coutiño et al., 2019). These new alternatives for organic fertilizers are more economical and easier to implement in rural areas, providing cleaner and less harmful production for the ecosystem, and contributing to the development of sustainable and environmentally friendly agriculture (Desmiwati et al., 2020).



Organic fertilizers are a strategy and proposal that can lead to environmentally friendly solutions for the agricultural sector (Rejani y Yadukumar, 2010). The transition towards the use of organic fertilizers instead of agrochemicals within peasant economies is incipient, but a constant effort has been made to achieve this transition, leading to more sustainable processes and healthier products (Martins et al., 2019). The introduction must be able to explain the rationality of the research carried out, so that it can be justified why research is important for the scope related to governance, taxation, and auditing in the field of community service. The introductory part of a study must be able to state the gaps that form the basis of the research (issue). The introductory section should cover the topic of the research conducted, the formulation and relevance of the research conducted with previous research, research problems, and research questions (Desmiwati et al., 2020). In the scientific article format, no literature review is allowed as in the research report, but it is realized in the form of a state-of-the-art literature review to show the scientific novelty of the article and question research.

METHODS

The present investigation is of a quantitative type. It mixed a descriptive and exploratory process about the object of study, where the bokashi-type fertilizer was developed as a strategy to address scarcity and apply it to cashew cultivation. A descriptive analysis of the viability of bokashi as a fertilizer was conducted, considering the results obtained in the first phase. Both aspects were considered to arrive at an optimal solution for the use of bokashi as an organic fertilizer for cashew. The results obtained through this provided indications on which direction should be taken regarding the development of the technology and the application of bokashi as an organic fertilizer.

Case study. For the case study, a productive unit of one of the participants who has been cultivating cashew for 7 years was selected. The participant voluntarily agreed to have their farm be the scenario of the investigation, which was developed in the municipality of Baranoa, Atlántico (Colombia). The Namasté farm is located in the municipality of Baranoa, Atlántico, with coordinates N 10°47'45" W 74°53'17", and an average temperature of 26°C. The farm's vocation is agricultural. The total area of the farm is 21.5 hectares, of which 4.6 hectares are dedicated to industrial cashew cultivation, with 1.6 hectares in production and 3 hectares in growth. In addition to this crop, there are 5 hectares of cassava, pineapple cultivation, and 1 hectare of mango in production. There is also a 100 m² area for bokashi production, and the property has all the necessary services for its operation. Once the study area and participant group were established, the experimental phase began, where the bokashi pile was constructed, which was later used as a conditioner for cashew cultivation.

Phase 1. Material preparation the Namasté farm was selected to produce bokashi, as it had an available area for this activity (Table 1).

Chicken manure from the laying hen beds of the Cartama poultry farm was used to obtain the organic fertilizer. Before preparing the bokashi, the chicken manure was left to air dry for eight months, achieving stabilization, reducing nitrogen concentration, and promoting its maturation process. This created a suitable scenario for decomposer microorganisms to initiate the maturation process and reduce the time required for bokashi maturation.

After the chicken manure maturation process, 2000 kg of it was used. For this, personal protective equipment, a wheelbarrow, two shovels, a geomembrane, and plastic bags were used.

Subsequently, vegetable charcoal from the farm was used. This was crushed into smaller parts to maintain a size ratio with the other materials used.



Table 1. List Of Materials and Quantities

Materials	Quantity	Description
Chicken Manure	2000 kg	Sources of Nitrogen, Phosphorus, Potassium, Ca, C, Fe, Mn, Zn, Cu, and B, improving soil fertility
Vegetable Charcoal	300 kg	Enhances soil physical properties, increasing aeration, water absorption, and heat absorption.
Cashew Leaves	30 kg	Optimizes nutrient penetration in the soil. Provides soluble micronutrients. Favors pH optimization.
Forest Soil	200 kg	Favors the initiation of microbiological activity in organic fertilizer production.
Molasses	2 kg	Food source in the fermentation process, benefits microbiological activity, source of K, Ca, Mg.
Yeast	125 grams	Efficient microorganisms (EM) to initiate the fermentation process.
Water	As needed	Facilitates the generation of a homogeneous pile, and provides moisture.

Source: based on the needs of the participants and what the Namasté farm offered. This list formed part of the raw material for composting

Phase 2: Preparation of organic bokashi fertilizer the methodology used for the preparation of the fertilizer is described below through the following steps:

2000 kg of chicken manure was transferred to the bokashi production area, and 300 kg of vegetable charcoal, 30 kg of cashew leaves, and 200 kg of forest soil from the same farm were added. (Refer to Table 1.)

Next, a mixture of efficient microorganisms (EM) was prepared. 125 grams of yeast and 2 kg of molasses dissolved in 20 liters of water were used. This mixture was left to rest for 3 days to facilitate the fermentation process of EM, which would be applied later to the organic fertilizer pile.

Then, a homogeneous mixture of all materials was prepared, and the EM was added (Figure The materials were homogenized using the turning technique, which facilitated the fermentation process. The temperature of the pile should rise to a maximum of 40°C, and the pH should be controlled at 6.0. Before forming the pile, a geomembrane should be placed in the work area to prevent direct contact between the material and the soil, and the pile should be covered throughout the process to protect it from the weather.

During the production process, periodic turnings of the pile should be performed every 7 days, and the first test should be conducted to determine the humidity percentage throughout the process. This involves collecting a sample of the material in one's hand, closing the hand, and applying pressure. If liquid seeps out between the fingers, it indicates a high humidity percentage, and if no



liquid is observed, it indicates that the material is too dry, and water should be added. It is worth noting that the EM application should be performed until the sixth week of the process.

Fertilizer production: in the maturation phase, which begins approximately in the eighth week, the temperature of the pile should be at ambient temperature, and the pH should be between 6.8 and 7.0. Finally, after 60 days, the bokashi is obtained.

Inferential data analysis Linear regression: inferential data analysis was performed through empirical tests, such as linear regression, to determine the relationship between the dependent variable pH and the independent variable temperature. This allowed for the analysis of the degree of interdependence and effect between both variables.

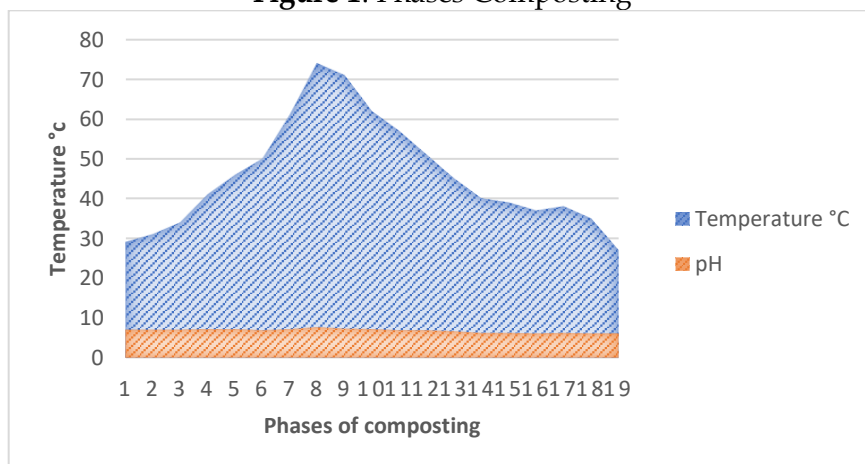
Pearson Correlation Analysis: subsequently, Pearson correlation analyses were conducted to examine the linear relationship between the variables and determine the correlation between them, i.e., whether one variable increases while the other decreases or vice versa.

ANOVA Analysis: furthermore, an analysis of variance (ANOVA) was used to compare the means within the dependent and independent variables, and to evaluate whether there is significance between them, measuring the variability of pH and temperature.

RESULT AND DISCUSSION

For 60 days, the composting process underwent three phases: mesophilic, thermophilic, and cooling/maturation. The pH and temperature of the composting process were monitored, and a visual inspection was conducted to evaluate its physical appearance. During this period, the composting pile was turned three times a day and covered with polyester plastic to prevent heat loss and maintain the fermentation process. As the days passed, the decomposition process accelerated (Figure 1). It was found that during the fermentation process, the pH was maintained between 5.9 and 7.5, while temperature variations were observed depending on the external temperature. From day 1 to day 60, the composting process had optimal conditions for its application in soils. At this point, the odor was earthy, and the color indicated that the composting process had reached its final stage or cooling phase.

Figure 1. Phases Composting



Statistical model to determine the relationship between the dependent variable (pH) and independent variable (temperature), a correlation analysis was performed, consisting of the following elements (tables 2, 3, 4 y 5):



First, the Pearson correlation was calculated, which indicated a positive relationship between the variables, i.e., as temperature increases, pH also tends to increase. Regarding bilateral significance, a value of 0.004 was obtained, indicating that the correlation between the variables is statistically significant. Next, a linear regression analysis was performed, which yielded a coefficient of determination (R-squared) of 0.390, indicating that temperature explains approximately 39% of the variability in pH. Additionally, an analysis of variance (ANOVA) was performed for the linear regression, which consisted of calculating the sum of squares for the regression, obtaining a value of 155.420. This indicates that the independent variable (temperature) explains a significant amount of variability in the dependent variable (pH). Therefore, this model explains a positive and moderate relationship between the independent variables, and although temperature manages to explain part of the variability in pH within the compost, the linear regression is statistically significant. Thus, it can be concluded that, within composting, pH varies according to temperature.

Table 2. Correlation table.

Variables	Temperature	pH
Temperature	Pearson Correlation	1
	Sig. (bilateral)	.624
	N	19
pH	Pearson Correlation	.624
	Sig. (bilateral)	.004
	N	19

Source: Own elaboration.

Table 3. Model Summary

Model	R	Corrected R squared	Corrected R squared	Standard error of estimation
1	.624	0.390	0.354	3.7832

Source: Own elaboration.

Table 4. ANOVA

Model	Sum of squares	gl	Mean Square	F	Sig.	
1	Regresión	155.420	1	155.420	10.859	.004
	Residual	243.317	17	14.313		
	Total	398.737	18			

Source: Own elaboration.



Table 5. Coefficients

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Error tip.	Beta		
1 (Constant)	56.772	3.069		18.496	.000
Temperature	.212	.064	.624	3.295	.004

Source: Own elaboration. This matrix was designed to identify key aspects of the characteristics of bokashi-type composting, given its artisanal origin.

Composting behavior according to the graph, the behavior of the bokashi composting process was normal, with high-temperature peaks during the thermophilic stage followed by a decline, indicating that the organic matter removal processes were effective in accelerating the decomposition process and producing an optimal substrate as a conditioner for cashew (Table 6). Furthermore, the bokashi production process did not require any adjustments, nor was calcium oxide applied as a buffer to stabilize the pH. This demonstrates that it was a successful process in which the expected results were achieved without the need for harmful chemicals.

Table 6. Qualitative characteristics of composting

Phase	Maturation	Thermophilic	Mesophilic	Phase
Odor	Organic matter	Decomposing organic matter	Earthy, humid smell	Earthy smell
Color	Varied according to organic solid waste	Brown and/or Ashen	Homogeneous brown	Intense black
Texture	N/A	N/A	N/A	N/A
Macrofauna presence	No presence	Much presence of edaphic macrofauna	No presence of edaphic macrofauna	No presence of edaphic macrofauna
Humidity	No humidity	Much humidity	Humid	No humidity
Compaction	Compact	Very compact	Uncompacted	Uncompacted and very sandy
Lixiviates	Present	Absent	Absent	Absent

Source: Own elaboration. This matrix was designed to identify key aspects of the characteristics of bokashi-type composting, given its artisanal origin.



Bokashi Production of total of 2.5 tons of bokashi was produced with optimal physicochemical conditions, with a pH of 6.9 and a cooling temperature of 29°C. Once the bokashi was ready to be used as a soil conditioner for cashew cultivation, it was applied in a 1.6-hectare pilot project as an alternative due to the scarcity of biofertilizers.

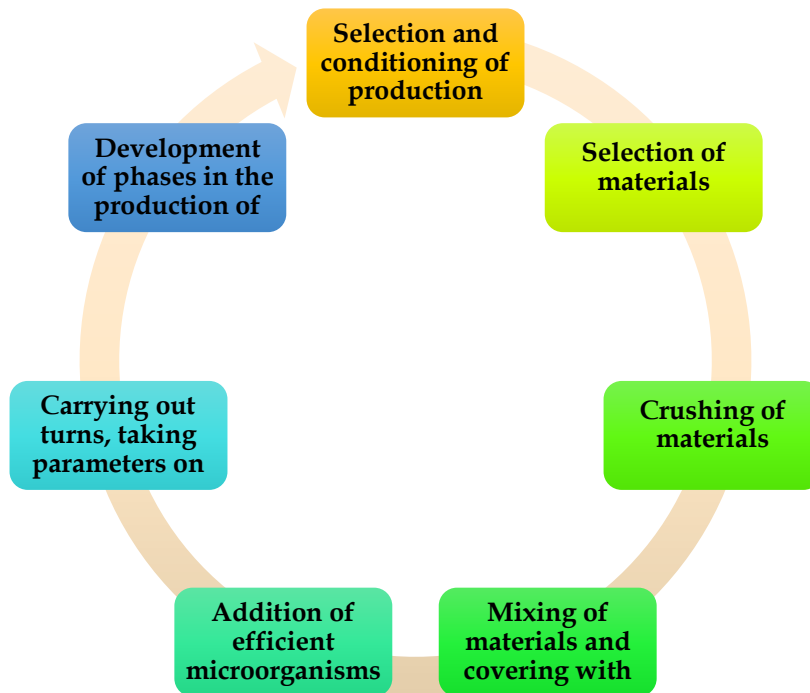
Bokashi-application and pilot the bokashi application was carried out manually on 156 cashew trees distributed over 1.6 hectares, with a distance of 10 meters between each tree, planted using the three-bulb planting technique. A team of 5 workers, along with 3 researchers, worked together to assess the benefits of the conditioner through 10 inspections over 5 weeks, which is the time it takes for the conditioner to be absorbed into the soil. After the bokashi application, it was observed that the soil moisture content remained stable, which is favorable for cashew cultivation. The fertilizer also had an indirect positive effect on the soil.

Proposed production model the production of bokashi organic fertilizer should be developed through seven stages, as shown in Figure 2. The first stage is the selection and conditioning of the production area, which requires designating a location near the cultivation area to facilitate the transportation of materials to the organic fertilizer production area. The second stage involves selecting materials that are crucial for achieving the desired inputs that favor bokashi production and are easily accessible. It is recommended to use organic materials produced near the production area. The third stage is the shredding of materials, such as charcoal, and cashew leaves, which must undergo a chopping process to ensure all materials are of the same size, facilitating the fermentation process.

The fourth stage is the mixing of materials and covering with a geomembrane. The shredded raw material should be placed on a geomembrane, then homogenized with the help of shovels, and finally covered with the same geomembrane to protect it from the elements. In the fifth stage, efficient microorganisms and water are added to the organic matter pile. To do this, a mixture of yeast, molasses, and water should be prepared three days in advance to favor the growth of efficient microorganisms (ME). These microorganisms promote and accelerate the fermentation of organic matter and should be applied until the sixth week of the process. Additionally, water should be added as needed to control the humidity percentage and favor fermentation.

The sixth stage involves periodic turning and in-situ parameter control. It is essential to perform regular turnings, which facilitate the homogenization of the pile and fermentation. During each turning, the parameters of temperature, humidity, and pH should be controlled. Finally, the development of the bokashi production phases must go through several stages. The first phase is the mesophilic phase, which occurs in the first weeks, where the pH tends to decrease, and the temperature does not exceed 40°C. Then, it passes to the thermophilic phase, which corresponds to the intermediate weeks, where the temperature rises to 70°C and a pH of 7.5 with an alkaline tendency. Afterward, it continues to the maturation phase, which occurs in the final weeks, where the temperature gradually decreases to ambient temperature, and a neutral pH is achieved, resulting in the production of bokashi.

Figure 2. Models for systematizing the methodological phases for bokashi-type composting. This figure compiles the relevant steps for the implementation of organic fertilizer



Source: Own elaboration

Studies on bokashi composting

The present study is in line with the authors of Mendivil-Lugo et al. (2020) who reference how the use of organic fertilizers supplies macronutrients such as nitrogen, phosphorus, potassium, and micronutrients to the soil, improving its chemical and physical structure, increasing water retention, quality, and optimizing productivity. According to Gashua et al. (2022); Month, (2023) this translates into generating greater benefits in the production of cashew (*A. occidentale*), reducing costs, improving its physical-chemical and biological properties, and maintaining the natural balance of the soil thanks to the formation of humus. Within this research, this balance was demonstrated by the relationship between the independent variable (Temperature) and the dependent variable (pH).

However, the present methodological proposal opens a path for cashew producers in the municipality of Baranoa; since it was demonstrated that bokashi can be an alternative solution to the crisis and shortage of agrochemicals, as expanded by Sari et al. (2022) who proposed that for the methodological proposal, the selection of materials, preparation of the same, mixing of materials, addition of efficient microorganisms, humidification, fermentation, drying, storage, and application in a cashew crop at the Namasté farm, with the collaboration of five farmers from the area. This study focused on presenting a methodological proposal for bokashi production.

The studies by Murillo-Amador et al. (2015) and Mosquera et al. (2016) mixed solid organic waste to achieve a bokashi-type composting and worked in a context where community participation and individual initiative play an important role in developing environmental solutions and using organic fertilizers as alternative inputs that contribute to sustainability. They also



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highlighted the potential of this solid organic waste to be recycled and transformed. This low-cost technique contributed to being a cheap and sustainable option from organic matter. The studies demonstrated that this solution is an achievement for soil recovery and vegetation. Finally, it is considered that this study also provides an alternative to the use of chemical fertilizers based on synthetic products, which harm the environment. Therefore, to achieve more sustainable agriculture, they recommend committing to the implementation of organic practices such as bokashi.

On the other hand, the research by Castaño et al. (2022) worked with pig sludge as a soil conditioner and improver for maize crops and determined the richness and abundance of edaphic macrofauna. This demonstrated that the applied doses were not sufficient to improve part of the soil overexploited by maize crops, since the levels of biodiversity of edaphic macrofauna were not dynamic. These two studies aim to improve the edaphological conditions in tropical crops through the application of composting methods that can, at some point, replace agrochemicals. This, in addition to being part of a viable solution for times of scarcity, contributes to the creation of sustainable productive systems that seek soil recovery without agrochemicals.

Rianti et al. (2021) and Wickham y Davis (2024) proposed an agile methodology for the elaboration of bokashi without specifying which crops it was directed to. Different from the present methodology that sought to overcome the deficiency of conditioner for cashew cultivation, their proposal was authentic and differentiated. However, it is recommended to expand this methodology to other crops of interest to the scientific community. In order to improve the production of these crops and obtain better results, it is important to continue exploring agile and efficient composting methodologies that allow the development fertilization strategies based on organic products. These practices would contribute to achieving more sustainable and low-cost agriculture in communities with limited resources.

According to Gashua et al. (2022) they found that the temperature of approximately 67°C rose rapidly to 6 days in the compost piles, which achieved the thermophilic stage rapidly. This contrasts with the current study where the temperature reached 74°C at 12 days, followed by a presumed decrease due to deficiencies in the carbon vegetable ash, which suggests experimenting with larger quantities. However, both studies share the objective of improving soil humidity, both for radish cultivation and for cashew. Therefore, it is recommended to consider the application of organic strategies such as bokashi in transitional or backyard crops without the use of agrochemicals as proposed by the study being discussed.

The studies by Wang et al. (2020) detected that the pH of the bokashi was 6.5 without alterations in acidification. This suggests that calcium oxide was not needed. However, in the present study, this chemical compound was used as a continuous measure to protect the pH at 7. This, according to the previous study, suggests that it is necessary to apply different bokashi based on different manures given the natural acidity with which composting is started, as some manures tend to acidify slightly. Similarly, to measure its efficiency in macronutrients and micronutrients, achieving a bokashi with optimal conditions.

CONCLUSION

This research achieved its objective, which was to propose a composting production model applied to the cultivation of cashew (*A. occidentale*). The development of composting was determinant and successful, allowing for the evaluation, measurement, and valuation of the temperature and pH variables, which are definitive in determining the state of bokashi-type



composting. This yielded a significance level of 0.004 between the dependent and independent variables.

It is also concluded that, for this type of composting, temperature has a strong impact on pH. Furthermore, it is proposed to explore traditional and qualitative methods to generate bokashi-type composting, with a subjective analysis within the examination of composting and subsequently purely qualitative variables such as temperature and pH. The composting process developed under optimal conditions, reaching an ideal cooling for its use and application. There were no setbacks in the stages of fertilizer development, which resulted in a very favorable outcome for continuing its application and addressing the scarcity problem.

Home-made bokashi production can be a viable solution to resolve the scarcity crisis in Colombia due to the impact related to the conflict between Ukraine and Russia. This is because tangible benefits have been found in terms of cost reduction, soil fertility improvement, increased food production, environmental preservation, and improved nutritional quality. These advantages are due to the collaboration between farmers and academics to share knowledge. The collaboration must continue to share new knowledge and develop sustainable and environmentally respectful solutions. Food security and environmental conservation are possible through the use of homemade bokashi, which contributes to increased agricultural production and better income for farmers. This project implements small-scale solutions in cashew cultivation to address problems related to agricultural production, the use of harmful chemicals, and input scarcity.

The positive results obtained with the bokashi production process demonstrate that it is a sustainable and effective practice to improve soil fertility, and opens up the possibility of a transition towards sustainable cashew cultivation. This technology has become an invaluable tool for farmers, as it allows them to enjoy greater economic benefits and a better quality of life. During bokashi production, in the mesophilic phase, it is important to add water as needed to control the humidity percentage, which favors fermentation and allows an increase in temperature up to 40°C maximum and pH to 6.0.

For the bokashi production process, it is important to perform periodic turnings, which favor the homogenization of the pile and fermentation. Similarly, performing the first test to measure the humidity percentage of the pile throughout the process is crucial. In the thermophilic phase, an increase in temperature to 74°C maximum and pH to 7.5 was observed, demonstrating the maximum microbial activity of the pile. At the end of this phase, a decrease in temperature and pH variables was observed, indicating the start of the maturation, stabilization, and bokashi obtention phase.

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