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Reuse of the biomasses generated during candied fruit and table olive industrial processing for dog feed production

Reaproveitamento da biomassa gerada no processamento industrial de frutas cristalizadas e azeitonas de mesa para produção de ração para cães

Reutilización de la biomasa generada en el procesamiento industrial de frutas confitadas y aceitunas de mesa para la producción de alimentos para perros

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Abstract

Organic waste is derived from production processes, the amount of waste generated from two factories participating in this work reaches approximately 2000t / year, directly impacting the environment, making areas conducive to the development of insects and pests attracted by the discarded residual food. The cost used in the correct disposal of this waste, directing it to the local landfill is approximately R $ 150,000.00 / year. Considering the great nutritional value present in biomass, this work aimed to reuse these residues to produce a dog food. For this, a methodology was created to treat these biomasses, transforming them into co-products for commercialization. With this, a formulation was developed incorporating the by-products of olives, papayas and oranges, plus other essential ingredients for dog food, complying with the current legislation, resulting in a product with high added value. The developed feed used 38% of the residual biomass in its composition, and compromised, through the simulated study, all the material generated by the industries, being able to reduce a large part of the disposal expenses to the sanitary landfill. The generation of revenue from the sale of biomasses has subtracted the expenses with landfill disposal, making the process economically viable in addition to proposing a sustainable solution to the manufacturing process.

Keywords: Organic waste; Co-product; Animal food.

Resumo

Resíduos orgânicos são derivados de processos produtivos, a quantidade dos resíduos gerados de duas fábricas participantes deste trabalho atinge aproximadamente 2000t/ano, impactando diretamente o meio ambiente, tornando áreas propicias a desenvolvimentos de insetos e pragas atraídas pelo alimento residual descartado. O custo empregado no descarte correto deste resíduo direcionando-os ao aterro sanitário local é de aproximadamente R$ 150.000,00/ano. Considerando o grande valor nutricional presentes nas biomassas, objetivou-se com este trabalho o reaproveitamento destes resíduos para a produção de uma ração destinada a cães. Para isto, foi criada metodologia para tratamento destas biomassas transformando-os em coprodutos para comercialização. Com isso desenvolveu-se uma formulação incorporando os coprodutos de azeitona, mamão e laranja, acrescidos de demais ingredientes fundamentais a alimentação de cães, cumprindo a legislação vigente, resultando em um produto com alto valor agregado. A ração desenvolvida utilizou 38% das biomassas residuais em sua composição, e comprometeu, pelo estudo simulado, todo o material gerado pelas indústrias, podendo reduzir grande parte das despesas de descarte ao aterro sanitário. A geração de receita com a venda das biomassas subtraiu as despesas com o descarte ao aterro, tornando o processo economicamente viável além de propor uma solução sustentável ao processo fabril.

Palavras-chave: Resíduos orgânicos; Coproduto; Ração animal.

Resumen

Los desechos orgánicos se derivan de los procesos de producción, la cantidad de desechos generados por dos fábricas que participan en este trabajo alcanza aproximadamente 2000t / año, impactando directamente el medio ambiente, haciendo que las áreas sean propicias para el desarrollo de insectos y plagas atraídos por los alimentos residuales desechados. El costo utilizado para la eliminación correcta de estos desechos, dirigiéndolos al vertedero local, es de aproximadamente R $ 150,000.00 / año. Teniendo en cuenta el gran valor nutricional presente en la biomasa, este trabajo tuvo como objetivo reutilizar estos residuos para producir un alimento para perros. Para esto, se creó una metodología para tratar estas biomasas, transformándolas en coproductos para su comercialización. Con esto, se desarrolló una formulación que incorpora los subproductos de las aceitunas, las papayas y las naranjas, además de otros ingredientes esenciales para la alimentación del perro, cumpliendo con la legislación vigente, resultando en un producto con alto valor agregado. El alimento desarrollado utilizó el 38% de la biomasa residual en su composición y comprometió, a través del estudio simulado, todo el material generado por las industrias, pudiendo reducir una gran parte de los gastos de disposición al vertedero. La generación de ingresos por la venta de biomasas ha restado los gastos con la disposición de los vertederos, haciendo que el proceso sea económicamente viable además de proponer una solución sostenible al proceso de fabricación.

Palabras clave: Residuos orgânicos; Coproducto; Alimento para animales.

1. Introduction

Due to the constant exploitation of natural resources by humans, a preservation trend with an emphasis on reuse and production of new materials from by-products has been observed. Fruit and pulp industries, among others, aim to use biomasses that would otherwise be discarded during the production process (Mota, et al., 2017).

Any material that can be biologically decomposed is termed biomass, further characterized as the accumulated matter in a given space, and can originate from animals or vegetables, among others (Fernandes, 2012).

The agriculture industrial sector produced the largest amount of waste per year, and an estimated tat 1.3 billion tonnes of biomass are generated worldwide (Sadh, et al., 2018). In Brazil, it is estimated that fruit processing for juice and pulp consumption or sale averages about 23 million tons per year (Okino-Delgado, et al., 2018). Of this total, from 30 to 40% consist in waste, containing compounds such as vitamins, minerals, fibers, among others.

Therefore, they comprise a by-product with added value and evidence waste in case of disposal (Nascimento Filho, et al., 2015). Brazil ranks first concerning papaya production, with over 15 million tons produced in 2013 (IBGE, 2014). Oranges, rank 2nd in the world's production rank, averaging 800 million tons per year, and again, Brazil ranks first in production (Sebrae, 2015). As reported by da Silva Gehlen et al. (2016), the Brazilian state of Rio Grande do Sul consists in 1,200 hectares of olive production, widely consumed in Brazil in various forms, such as stuffed, preserved and fresh. In this regard, Alcaide et al. (2010) indicates out that for 1000 kg of olives used in olive oil extraction and production, 800 kg are wasted for 1000 kg of olived.

"*Pet Food*" is defined as the segment of the pet market that covers the entire food production chain. Commercial animal feed estimation can be classified, in terms of processing, into three basic types: drought, semi-moist and moist. Dry foods make up the largest segment of the pet industry and are 95% captured by extrusion technology (SPEARS, et al, 2004). The use of biomass as raw material for animal feed following current Brazilian legislation parameters can be an economically viable process, while also contributing to minimizing environmental impacts caused by incorrectly disposed residues. Brazil ranks 3rd in domestic animal product sales, including the food segment, and of the R$ 20.3 billion made in 2017, 68.6% correspond to the animal feed segment, Brazilian pet products industry association (ABINPET, 2016).

In view of the above, the aim of the present study was to characterize and evaluate papaya, orange and olive residues generated from a candied fruit and canned olives industry located in southern Rio de Janeiro, in the city of Três Rios. A simulation of the animal feed production line using this biomass was also proposed, as well as the use of other compounds, in order to add nutritional value.

2. Material and Methods

2.1 Papaya and orange waste processing

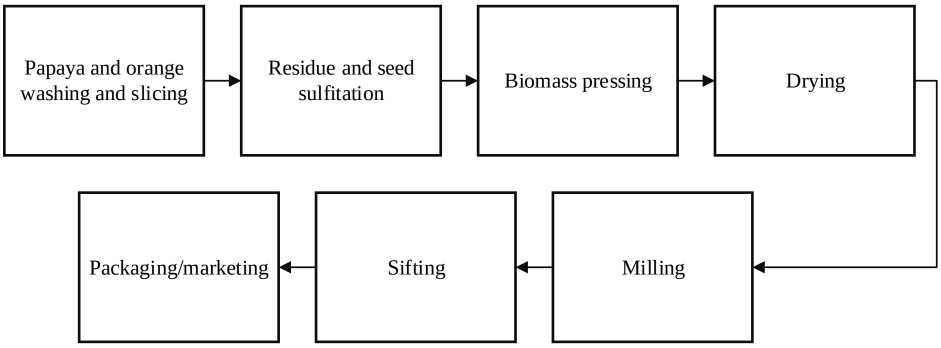
Currently, candied fruits are produced from a papaya mixture at the Giannone e Cia Ltda factory, where they are subjected to various processes up to the sugar crystallization stage. Thus, the biomass generated in the manufacturing process of crystallized fruits basically consists of seeds and pulp generated from the waste process (Figure 1).

Figure 1 – Papaya and orange waste.

Source: Authors.

The amount of waste generated (Figure 1) reaches approximately 2000t / year, directly impacting the environment, making areas conducive to the development of insects and pests attracted by the discarded residual food. The following sequence was developed for the production of a co-product from papaya and orange residues, displayed in the flowchart presented in Figure 2.

Figure 2 - Papaya and orange biomass processing flowchart.



Source: Authors.

According Figure 2 in natura papayas and oranges were subjected to the cutting and slicing process, then sanitized with highly pressurized chlorinated water, in order to remove papaya pulps, part of bagasse and orange juice, in addition to seeds. As this process is applied to a humid material which is easy to deteriorate, the sulfitation step consisted of sulfiting the material with a metabisulfite solution (600 ppm), in order to contain microorganism growth and proliferation. The material remained in this solution for at least 12 hours, guaranteeing preservative absorption. After the preservative absorption period, the product was then subjected to the pressing step, in order to remove water. Subsequently, the product was directed to drying ovens at controlled temperature to prevent burning, leading to sterilization. The dry product blocks generated after drying in greenhouses were then crushed to less than 80 mesh (0.177 mm) granulometry. The papaya and orange residue in powder form (flour) is then ready to be packed in plastic packaging or kraft paper for later use or commercialization. It is important that the packaging avoid environmental moisture absorption.

2.2 Industrial canned olive processing

To obtain sliced, pitted and stuffed olives, commonly found in preserves in markets, the fruits must undergo a mechanical ginning process, which consists of the separation of the pulp from the core centered in the fruit. All products generate high amounts of waste (25% of the total weight of the initial olive weight), consisting of the pit, with a small amount of pulp (Figure 3).

Figure 3 - Olive residue obtained in the pit-removal process.

Source: Authors.

As seen in Figure 3, after removal, the pits undergo a pulping process, required to remove part of the remaining material, which could be used in other processes, resulting in cleaner and drier pits, as well as to improve the drying process. The pit drying stage consists in natural drying, due to the large product volume, in an open area. The washing step was carried out using chlorinated water (0.2 to 2 ppm) in order to remove physical and microbiological impurities that may have occurred during the drying process, due to high exposure subject to contact with insects and/or animals. After immersion in chlorinated water, the pits proceeded to a heat treatment, in order to remove the washing-generated moisture, as well as to guarantee microbiological decontamination prior to the grinding process. Subsequently, the pits undergo a first break in a hammer-type mill, due to their extreme hardness, followed by a grinding process, in order to obtain a powder with particle size greater than 80 mesh. The olive pit powder was then subjected to a sieve step (80 mesh, 0.177 mm aperture), to ensure the absence of larger pieces, which can be harmful to domestic animal teeth. After sifting, the olive pit powder, was packed in plastic packaging or kraft paper for later use or sale. It is important that the packaging avoid environmental moisture absorption. The flowchart of this process is detailed in Figure 4.

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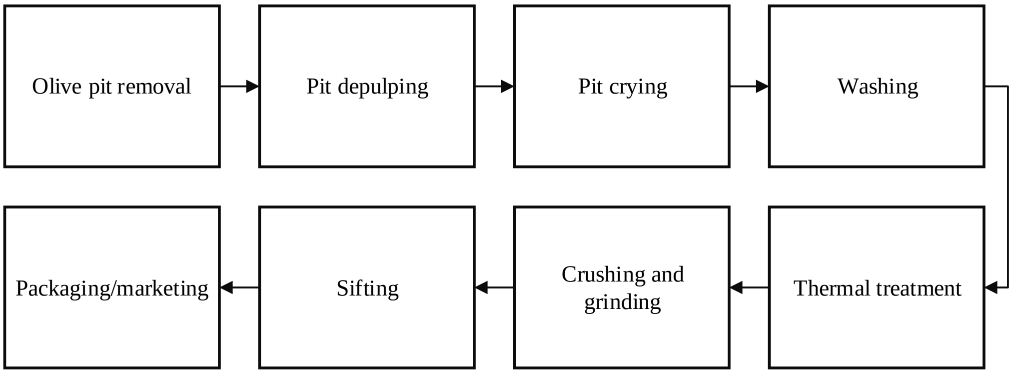
Figure 4 - Olive residue processing flowchart.



Source: Authors.

2.3 Residue (coproduct) characterization

The residues were characterized according to physical-chemical parameters following the methodology proposed in the Guidance manual for the food industries, Analytical Standards of the Adolfo Lutz Institute (Physical-chemical methods for food analysis) and AOAC Official Methods of Analysis. The analyses were carried out at the accredited laboratory (Cetal S/S Ltda - Technological Center for Food Analysis). Characterizations were carried out supported by the current Brazilian Ministry of Agriculture, Livestock and Supply [MAPA] (2009), legislation, Ordinance No. 3, of January 22, 2009, which establishes the criteria and procedures for the registration of establishments and products, for labeling and advertising and for registration exemptions for products intended as pet animal feed.

2.4 Dog food development

Table 1 presents the main limits established by the current legislation (Ordinance No. 3, of January 22, 2009, of the Ministry of Agriculture, Livestock and Supply).

Table 1 - Guarantee level limits established by the current legislation.

Parameter	Limit	Value for feed intended for adult dogs (%)
Moisture	Maximum	12.0
Crude protein	Minimum	16.0
Fat (ethereal extract)	Minimum	4.5
Mineral matter	Maximum	12.0
Attribute	Limit	Calorific value (Kcal/kg)
Calorific value	Maximum	3.100*
	Minimum	900**

* For feed formulated with up to 12% moisture. ** For foods with up to 65% moisture.
Source: Brasil (2009).

As indicated in the Table 1, for foods with over 65% moisture during feed development, compositions are defined in different ways and ingredients, depending on the desired objective and the cost of raw materials for feed the production. The feed composition developed herein was intended adult dogs. Based on this guideline, both raw materials and biomasses with good palatability, digestibility, economic viability and within the parameters established by the legislation were used. Due to its nutritional characteristics, this is a product displaying advantages concerning animal feed formulation, enabling better cost/benefit ratios.

Along with pork meat, hydrolyzed feather meal was used due to its high protein load, varying by 85%, and its high digestibility, as well as blood meal, attributed for consisting of 90% crude protein in its compositiona and high digestibility, as highlighted by the Patense company (Patense, 2019). A vegetable portion was added using soybean meal and papaya and olives biomasses, making up the required protein content as set by law. The average market formulation protein content ranges from 10 to 30%, according to brand.

With regard to fats (ethereal extract), bovine tallow and viscera oil were used as an option to avoid vegetable fat addition, since the olive biomass already contains significant residual amounts of fat and were used to achieve the required values.

Concerning mineral matter, poultry offal flour, in addition to bones from swine flour, was added, which adds to protein 65% protein, mineral matter 16%, and ethereal extract, 10%. Papaya and olives biomasses were added to the final composition of this item. Soy flour and sorghum flour were used concerning carbohydrate energy. Sorghum flour was used because it is a low-cost option in relation to other cereals, in addition to being gluten-free and with better palatability when compared to corn and soybeans. It also presents high levels of nutrients and bioactive compounds, with high antioxidant capacity, which can contribute to health promotion. Fibers, anthocyanins, phenolic acids, tannins and resistant starch are also noteworthy, Brazilian Agricultural Research Corporation [EMBRAPA] (2016). The papaya biomass, as it contains sugars from fruit crystallization, increased carbohydrate composition.

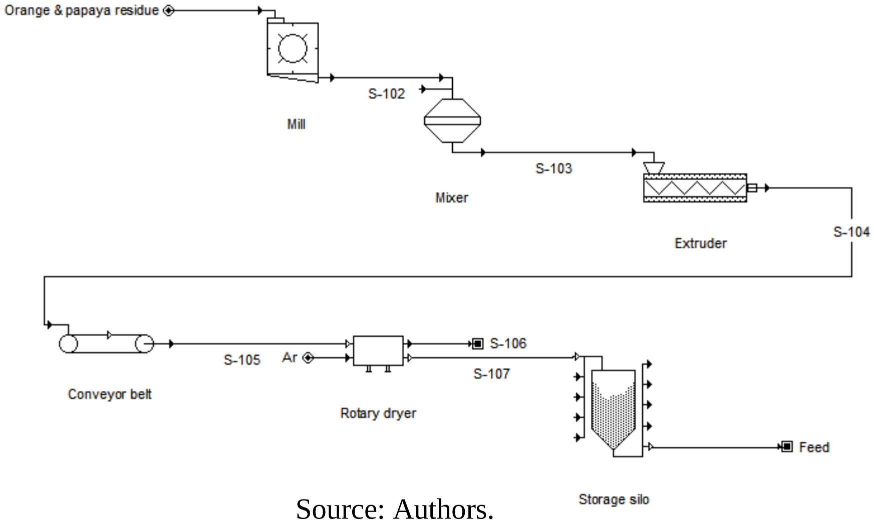
In addition, bone meal was used as a source of calcium and minerals, uniting the papaya, orange and olive biomasses, which contain fiber and vitamins, while viscera flour contains 65% crude protein, antibacterial additives and antioxidant additives, as well as adequate digestibility of significant importance for the final formulation. The final formulation was then prepared from this combination of ingredients, where all dry ingredients were weighed at the set concentration and mixed until homogeneity.

A single screw RX PQ Labor 24, Inbramaq extruder with semi-industrial capacity was used under the following conditions: three helical liners; wide-pitch thread, one outlet, compression ratio of 2.3:1 and length/diameter ratio (L/D) of 15.5:1; subtraphile of 3.01 mm holes; draws from a 2.93 mm hole; temperatures of 50 °C, 70 °C, 90 °C and 120 °C in zones 1 to 5, respectively, and feeding speed of 265 g/min. These conditions followed the standard used for corn grits in snack extrusion (Paula & Conti-Silva, 2014).

2.5 Production process simulation

To better understand the process and of the proposed fruit residue, this step was also based on the current legislation (Table 1) set in Mapa Ordinance No. 3, of January 22, 2009. Process simulators have become essential tools in studies and project planning to test the viability of an animal feed production line. Herein, the SuperPro Designer® process simulator was used to develop a flowchart of the proposed feed production process (Figure 5). The SuperPro Designer simulator provides equipment sizing, cost calculation, economic evaluation, mass and energy balances, and is easy to handle, leading to quick and assertive responses (Intelligen, 2019).

Figure 5 – Animal feed process using the SuperPro Designer® process simulator.



Source: Authors.

At the beginning of the process, the mill aims to crush the biomass with the other feed components, in order to reach the same particle sizes.

The extruder can be worked with different types of feed forms according to the type and breed of the animal, with the possibility of changing plates in case any parameter requires adjustment. The extruder may apply heating, up to 100 °C at most, as this may deactivate some enzymes according to the raw material.

A conveyor belt was used in the simulation to represent processed material transport to the rotary dryer. The rotary drying process was used to obtain feed within the moisture range established by quality standards. Fat and flavorings are added at this stage. Subsequently, the product is stored in a silo, available for packaging or bulk shipping.

The feed composition of the feed simulation process consisted in 20% papaya pulp with seed and 10% orange pulp, while 70% comprise other inputs (all other compounds and their respective required amounts, such as corn grains, cereals and chicken viscera flour, among others, to be added according to the desired composition. The feed mass consists in 500 kg per batch. The process was studied so that the biomass fractions enter as part of the feed and its inputs.

3 Results and Discussion

After processing the generated waste, the biomass flour is characterized as displayed Figure 6.

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Figure 6 – Processed papaya, orange and olive residues.

1 – papaya biomass, 2 – Orange biomass and 3 – olive biomass
Source: Authors.

The biomass characterization analyses results are displayed in Table 2.

Table 2 - Orange and papaya residue composition.

Parameter (g/100g)	Papaya with seed	Orange	Olive
Moisture	74.73	86.15	21.98
Crude protein	1.64	1.37	3.40
Fat (ethereal extract)	0.3	0.3	13.50
Mineral matter	11.7	0.48	1.62
Carbohydrate	11.63	11.7	4.10
Calorific value (Kcal/kg)	552.8	505.1	137.00

Source: Authors.

As noted in the results, the papaya and orange biomasses contained low protein and fat contents, but presented a significant amount of mineral matter and energy value, along with fibers and excellent palatability. The olive biomass contained a significant amount of vegetable fat. These results are important in the formulation development. Table 3 displays the amount of each ingredient included in the proposed animal feed for adult dogs.

Table 3 - Feed formulation.

Ingredients	**%**
Pork meat and bone meal	10
Sorghum flour	10
Hydrolyzed feather meal	8
Soybean meal	5
Papaya biomass	**20**
Orange biomass	**10**
Olive biomass	**8**
Offal oil	3
Bovine tallow	3
Poultry offal meal	15
Blood Flour	8
Total	**100**

Source: Authors.

The high crude protein digestibility from soybean meal demonstrates that this ingredient is well used by dogs, and can enrich commercial formulations, especially when associated with protein sources of animal origin, for greater adequacy of essential amino acids, mainly methionine and cystine.

Table 4 displays the nutritional characterization obtained for the proposed feed compared to the Mapa recommended data. This comparison indicates that the feed contains satisfactory levels recommended for commercialization.

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Table 4 - Nutritional characterization of the developed adult dog feed.

Parameters	Ordinance (Mapa, Brasil, 2009)	Developed feed
Protein	Min. 16 %	24.80 %
Mineral Matter	Max. 12 %	11.90 %
Ethereal Extract	Min. 4.5 %	8.50 %
Moisture	Max. 12 %*	7.0 %
Calorific value	Max. 3100 kcal**	317 (kcal)/1325 kJ

* For feed formulated with up to 12% moisture.
** For food with less than 65% moisture.
Source: Authors.

Comparing the results of the analyses presented in Table 2 with the established limits displayed in Table 1, high moisture is noted, possibly becoming a problem to be solved during the by-product process. However, a significant moisture loss in the final product is noted after drying, resulting in agreement to established limits. Concerning minimum limits, crude protein and fat are noteworthy, demonstrating the need to add other inputs to meet the basic Ordinance limits. Mineral matter and caloric value were within the established limits, although the papaya pulp with seed is very close to this value compared to mineral matter.

Comparing the analyzes carried out in Table 2 with the limits established by the legislation in force in Table 1, there is a high level of humidity, and a possible problem to be solved during the by-product process. However, there is a significant loss of moisture in the product that follows the parameters proposed by the legislation. This loss occurs in the unit drying operation. The produced feed presented favorable conditions for extrusion. Figure 7 indicates the feed before (homogenized ingredients) and after the extrusion process.

Figure 7 - Feed before and after the extrusion process.

Source: Authors.

Extrusion was performed according to Figure 7 and cannot be tested for other types of extrusion, due to the amount of sample. Regarding productivity data, the simulation presented a scenario with the estimated waste consumption (by batch and annual) intended for the production of the proposed feed, considering 7,914 hours per year, or 330 days, with continuous 24-hour production, totaling 990 batches per year. Table 5 displays the mass balance performed by the software.

Table 5 - Mass balance as set by the software for feed production.

Material	Kg/year	Kg/batch
Other inputs	346,500	350
Orange residue	49,500	50
Papaya residue	99,000	100
TOTAL	495,000	500

Source: Authors.

The use of biomass in the dog feed production process is satisfactory, as, despite supplying only a fraction of the required nutrients, biomass replaces some of the material that would be spent and contains moisture for cooking, leading to savings. It also reuses waste that would be discarded and consequently lead to environmental impacts. The total input mass is of 500 kg and the total output mass is equivalent to 433.830 kg (66.17 kg of consumed water). The other components alter the component mass percentages, due to drying, leading to moisture loss, increasing nutrient contents in the dry mass.

4 Conclusions

The present study evaluated the reuse of biomass generated in the industrial processing of candied fruits and table olives for the production of dog feed as a proposal for the development of a new product for waste-generating companies.

The results are within the norms of the Brazilian Ministry of Agriculture no. 81, December 19th, 2018, for the commercialization of co-products developed using residues from food and animal industries for incorporation in animal feed.

The developed feed comprised 38% of the residual biomass and took advantage of material generated by the evaluated industries, reducing landfill disposal expenses. The generation of revenue from biomass sales tends to make the process economically viable, while also proposing a sustainable solution to the manufacturing process.

The extrusion results confirmed the viability of the mixture for feed manufacture, suggesting margins for the market trend in "clean and clear" labels, due to the appeal of using fruit for feed production.

Some adjustments should be performed in order to establish the final product according to the composition specified in Table 1, thus obtaining product quality and complete verification of the current standard.

As a continuation of the study, it is proposed to carry out new analyzes of the product regarding nutritional parameters in order to validate the developed formulation and to incorporate other biomasses that complement the composition to minimize costs.

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