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ORIGINAL ARTICLE

Development of a pap-like product using cocoyam (*Xanthosoma sagittifolium*) as raw material

Desarrollo de un producto tipo papilla utilizando malanga (*Xanthosoma sagittifolium*) como materia prima

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Abstract It was developed two formulations of an agro-industrial pap-like product using cocoyam (*Xanthosoma sagittifolium*) as raw material by defining a technological process that permits the manufacturing, at an artisanal level, of a product with good quality and acceptance with adequate stability during its storage. A market study was conducted with 300 consumers to estimate their preferences and attitudes toward buying the product, including those over 20 years old who would buy it. Both formulations of the cocoyam log fulfilled the sanitary and physicochemical specifications established for this product type. No significant difference ($p \leq 0.05$) in the consumer's preference, independent of age groups for one of the formulations. In contrast, the other formulation was preferred ($p \leq 0.05$) by persons between 66 and 75 years old. The leading cause of deterioration in both formulations during storage was the acidification associated with microbial growth.

Keywords *Xanthosoma sagittifolium*, cocoyam, pap-like product, physical-chemical characterization, storage.

Resumen Se desarrollaron dos formulaciones de un producto agroindustrial similar a la papilla utilizando como materia prima la malanga (Xanthosoma sagittifolium), definiendo un proceso tecnológico que permita elaborar a nivel artesanal un producto de buena calidad y aceptación con una adecuada estabilidad durante su almacenamiento. Se realizó un estudio de mercado con 300 consumidores para estimar su preferencia y actitud de compra del producto, siendo los mayores de 20 años quienes adquirirían el producto. Ambas formulaciones de la malanga cumplieron con las especificaciones sanitarias y fisicoquímicas establecidas para este tipo de producto. No se encontró diferencia significativa ($p \leq 0.05$) en la preferencia de los consumidores, independientemente de los grupos de edad, para una de las formulaciones, mientras que la otra formulación fue preferida ($p \leq 0.05$) por las personas entre 66 y 75 años. La principal vía de deterioro encontrada en ambas formulaciones durante su almacenamiento estuvo relacionada con la acidificación asociada al crecimiento microbiano.

Palabras clave *Xanthosoma sagittifolium*, malanga, producto similar a la papilla, caracterización físico-química, almacenamiento.

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PUBLIS EDITORIAL

Introduction

The effective development of new products has converted into a key element for competing in a world of continuous changes and shorter lifecycles, characterized by rapid changes in the necessities of consumers, as much as in technology, thus causing those existing products to become obsolete much quicker (Pascucci et al., 2023). Many authors have shown that new products represent an increasing part of companies' benefits. Nevertheless, the failure rate of new products continues to be high (Castellion & Markham, 2012).

Different terms are used for this activity depending on the discipline, for instance, the development of new products in marketing and direction, innovation in research and development, and design in engineering (Edwards-Schachter, 2018). Numerous studies have focused on identifying the critical factors that influence the market success of new products to enhance the efficiency of the development process. The development process includes two stages: (i) product development (conceptualization, preliminary design, detailed design, tests, and manufacture) and (ii) product launch.

Products that have had success on the market are generally those with incremental innovations or reformulated products developed in a short period that offer greater innovation than the competition and are perceived by clients as different from the existing ones (Castellion & Markham, 2012).

Market studies are carried out to determine if a product satisfies the specification and design standard, using product samples only sold to specific consumers or in specific geographical locations. Then, the final phases, related to the manufacturing and launching, will be undertaken depending on whether the initial product design was accepted, modified, or rejected (Pascucci et al., 2023).

As far as we know, this is the first paper in which cocoyam (*Xanthosoma sagittifolium*) is proposed for manufacturing a pap-like product. However, in Grenada, it is known as tannia log, a traditional food prepared at the home level and used at different times of the day and in various settings, such as breakfast. It could be an innovative and engaging commercial product and an alternative for reducing postharvest losses due to an excess in the production of this tuber. It could also offer consumers a ready-to-eat product, blurring the lines between culinary traditions and food technology.

Therefore, this study focused on creating a new agro-industrial product resembling pap, utilizing cocoyam as the primary raw material. The objective was to establish a technological process that enables artisanal production while ensuring high quality, consumer acceptance, and suitable storage stability. A market study was conducted to estimate the preferences and attitudes of potential customers toward buying the product.

The work takes advantage of the availability of technology for the preparation of porridge to propose the use of cocoyam (*X. sagittifolium*) as a raw material to obtain a pap-like product since in Grenada it is a traditional food of its gastronomy. It is prepared at home and used at different times of the day and in various settings, such as breakfast, so its industrialization would be convenient for consumers and would not entail changes in consumption habits. It could be an innovative and engaging commercial product and an alternative to reduce postharvest losses due to excess production of this tuber and offer consumers a ready-to-eat product, blurring the lines between culinary traditions and food technology.

Methodology

A market study was conducted in Grenada with a sample of 300 persons divided into three age groups: 15-20, 21-49, and 50-65. A two-question questionnaire was applied to obtain opinions on their liking for the cocoyam log and the possibility of its commercialization.

Cocoyam (*X. sagittifolium*) cv. White cultivated on commercial farms was used. These were selected generally, considering they were free from visible defects, mechanical as much as microbiological. The root crop was characterized through the determination of humidity (AOAC, 2016), starch (AOAC, 2016), proteins (AOAC, 2016), fats (AOAC, 2016), total carbohydrates by difference, dietary fiber (AOAC, 2016), calcium (AOAC, 2016), iron (AOAC, 2016) and ascorbic acid (AOAC, 2016).

Condensed milk completed the formulation of the cocoyam log. The local supermarket also obtained table salt and spices such as nutmeg, powdered cinnamon, and bay leaves. Sodium benzoate and citric acid were used as preservatives. Table 1 shows the formulations for producing the cocoyam log at a laboratory level. These formulations were designed considering the taste of the Grenadian public and the traditional production method of this productrelevant content on both candidates' accounts.

Table 1. Cocoyam log formulations

Ingredient (%)	Formulation 1	Formulation 2
Cocoyam	26.38	13.128
Water	51.53	64.76
Condensed milk	20.46	20.2
Cinnamon	0.31	0.61
Bay leaf	0.62	0.61
Nutmeg	0.31	0.61
Salt	0.31	-
Citric acid	0.04	0.041
Sodium benzoate	0.04	0.041

Figure 1 shows the technological flowchart for elaborating the previously described cocoyam log formulas. Once selected, the cocoyam was cleaned with water to eliminate dirt-encrusted and other impurities that could have been present. After, it was peeled manually and weighed. The cocoyam was mixed and blended with spices and a part of the water, previously boiled with bay leaves, for different periods to obtain different textures for each formulation. The mixture was transferred to a stainless-steel pot and was cooked with the rest of the water. Upon cooking, the preservatives and the milk were added. Once finished, the product was bottled in glass containers of 42 g, sterilized previously, to facilitate a better process of sensorial evaluation among potential consumers.

The products were characterized through physicochemical

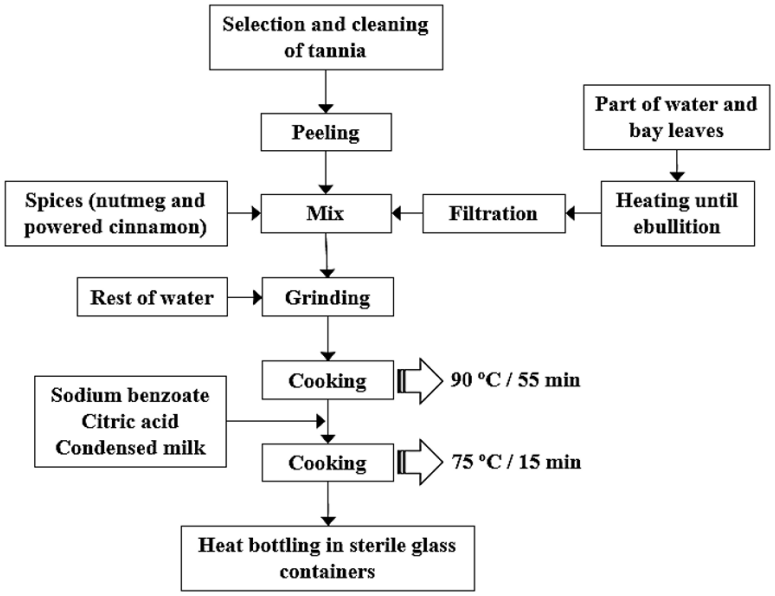

Figure 1. Technological flowchart for the elaboration of the cocoyam log formulas.

analysis such as determination of humidity content, starch, proteins, fats, carbohydrates, dietary fiber, calcium, iron, ascorbic acid, acidity (ISO 750, 2001), pH (ISO 1842, 1991), soluble solids (ISO 2173, 2003) and density. In addition, microbiological analysis of total plate counts (NC-ISO 4833, 2002), coliforms (NC-ISO 4832, 2002), fungi, and yeast counts (NC-ISO 7954, 2002), were carried out.

Quantitative Descriptive Analysis (QDA) (Sidel et al., 2018) was used to evaluate the sensory qualities of the cocoyam log. Ten trained judges evaluated products over a structured scale of 15 cm demarcated at both ends. The panelists proposed attributes using the controlled association method (Damasio & Costell, 1991). The terms were eliminated via open discussion with the judges, as established by criteria reported in ISO 11035 (2015). The sensory attributes used in the present research were color, typical odor, residual taste, sweetness, flavor, viscosity, texture, and overall quality.

A sample of 80 potential consumers was used for hedonistic tests. The consumers were given a questionnaire with a 7-point scale, and they responded based on the intensity of their likes for the two pap-like formulations.

Once elaborated, the two pap-like products were stored at 22 °C for 70 days to evaluate the behavior of some of their physicochemical attributes (pH, acidity, soluble solids, and density) and microbiological indicators such as total plate count (NC ISO 4833, 2002), total coliforms count (NC ISO 4832, 2002) and fungi and yeast count (NC ISO 7954, 2002).

The results were analyzed by ANOVA using Statistica software (version 7, 2004, StatSoft. Inc., Tulsa, USA). Duncan's multiple range test ($p \leq 0.05$) was used to determine

Table 2. Market study to know the Grenadian consumers' aptitude for the cocoyam log

Answer	Gender	Age groups (years old)								
		15-20			21-49			50-65		
		Yes	No	Other[c]	Yes	No	Other[c]	Yes	No	Other[c]
To question 1[a]	M	16	1	0	97	3	0	26	5	0
	F	18	4	0	95	12	0	22	1	0
To question 2[b]	M	7	10	0	72	27	1	22	8	1
	F	7	15	0	50	57	0	14	9	0

[a]: Do you like cocoyam log?
[b]: Would you buy tannia log at any of our local supermarkets?
[c]**:** Maybe/I do not know.

sample differences.

Results and discussion

The design, development, or innovation process begins with a series of ideas and ends with the specification of a product, service, or process, which necessarily involves a market survey. Table 2 presents the results obtained from the market survey in this paper, which correspond to a sector of the population that makes up the Grenada group of potential consumers of the product developed.

There was no significant difference ($p \leq 0.05$) between groups for the first question. Each group reported that they like porridge-based cocoyam. As for the second question, there was no significant difference between groups about buying a commercially based cocoyam porridge ($p \leq 0.05$). There was more to buy than product trends in the last two groups in the former. They are more likely to buy the latter two groups based on cocoyam porridge because they are older and have the most extended consumption of the product, developing a taste for it. Knowing that the first group consists of young people who are mostly not students and workers, the availability of money could have influenced his decision not to buy and access more products promoted among young people.

Making a comparison between sexes can report that there was no significant difference ($p \leq 0.05$) for consideration for question one, while there was a significant difference ($p \leq 0.05$) between sexes for question two, being the male sector that would buy it. Porridge-based cocoyam is a food that has been part of the Grenada diet for many years, and it has remained part of their folklore. It is said that this food has aphrodisiac effects, so men more popularly consume it.

Table 3 shows the composition of macronutrients and micronutrients of raw cocoyam used as feedstock to produce the two formulations based on the cocoyam porridge shown. The cocoyam used throughout this research was similar to the results published by Aráuz & Ñurinda (2009). Cocoyam has a macronutrient content, such as carbohydrates (20%), protein, and fat (0.25%), similar to that reported. Similar values were also reported in terms of humidity (73%), dietary fiber, and micronutrients such as ascorbic acid calcium (20 mg/100 g) and iron (1 mg/100 g).

In addition, micronutrients, such as calcium, have a value

Table 3. Physicochemical composition (water base) of the raw cocoyam and the cocoyam log formulas

Parameter	Raw cocoyam	Formulation 1	Formulation 2
Humidity (%)	73.0 (1)	72.0 (1)	77.0 (1)
Starch (%)	26.0 (0.2)	8.2 (0.3)	7.1 (0.2)
Proteins (g/100 g)	2.3 (0.5)	2.3 (0.2)	2.0 (0.2)
Fats (g/100 g)	0.25 (0.7)	2.4 (0.8)	1.5 (0.6)
Carbohydrates (g/100 g)	20.0 (0.8)	14.6 (0.5)	12.0 (0.7)
Dietary fiber (g/100 g)	1.6 (0.6)	0.35 (0.3)	0.2 (0.5)
Calcium (mg/100 g)	20.0 (0.3)	30.0 (0.2)	34.0 (0.2)
Iron (mg/100 g)	1.0 (0.2)	0.7 (0.2)	0.6 (0.1)
Ascorbic acid (mg/100 g)	7.4 (0.8)	6.7 (0.7)	5.4 (0.5)
pH	-	7.27 (0.05)	6.99 (0.08)
Acidity (% w/w acetic acid)	-	0.064 (0.02)	0.072 (0.03)
Soluble solids (ºBrix)	-	22.5 (0.5)	14.5 (0.4)
Density (kg/L)	-	1.093 (0.005)	1.055 (0.004)

Mean (Standard deviation); n= 3.

of 20 mg/100 g compared to the same data as the nutritional value of the Cuban cocoyam (18 mg/100 g). Differences between values might be attributable to differences in the soil type, nutrients that have this soil, agricultural practices, fertilizer, and others. The moisture content of cocoyam can also be compared with other tubers, as potatoes have an average of 75.05% (Wada et al., 2019).

The mean values of physicochemical indicators evaluated for the newly developed product are shown in Table 3. Decreased moisture content in formulation 1 (72%) but increased in formulation 2 (77%). This change could be attributed to two factors. It is, therefore, expected that the final product will have a decrease in moisture content due to evaporation losses. However, referring to the formulation of the two products, it can be seen that a certain amount of water, which therefore increased the moisture content in the product, was added.

If starch is evident, there was a dramatic reduction in the initial value. The product obtained in Formulation 1 produced a value of 8.2%, while that of Formulation 2 was 7.1%. Starch is a polysaccharide that undergoes gelatinization when subjected to a temperature of 55-70 °C (Tetlow & Bertoft, 2020). This process is defined by the retention of water by the starch, resulting in the disruption of the amylose and amylopectin present. The involvement of any component will result in an impairment of securities initially submitted.

As for the protein, there was little involvement of this macronutrient. Formulation 1 reported a value of 2.3%, while formulation 2 had a value of 2% protein. One factor that may have influenced the temperature reached was not exceeding 100 °C, which is the temperature at which reported reactions such as the Maillard reaction (Kchaou et al., 2019) occur.

Formulation 1 was worth 2.4%, while Formulation 2 had a value of 1.5%. Referring to the formulations (Table 1), condensed milk provides nutrients such as carbohydrates and fat. One of the agents influencing the alteration of fat is the temperature; high temperatures can lead to undesired reactions such as lipid oxidation, which is responsible for the rancid taste of food (Geng et al., 2023).

The two formulations reported a decrease in carbohydrates. Table 1 shows that water was added to dilute the cocoyam content. By increasing the substrate volume, the proportions of macro- and micronutrients tend to decrease. In comparison, formulations 1 and 2 showed 14.6 and 12% values, respectively, which provided 20% crude cocoyam.

Depending on the amount of soluble dietary fiber in the cocoyam, it could have been eliminated or reduced during cooking, resulting in a lower than raw cocoyam submitted content. Cocoyam raw provided a value of 1.6%, whereas formulations 1 and 2 decreased to 0.35 and 0.2%, respectively. In addition, as water was added in both formulations, one can arrive at the same conclusion about carbohydrates.

The calcium content increased significantly in both formulations (30 and 34 mg/100 g) compared to the raw cocoyam (20 mg/100 g). Condensed milk has a value of 260 mg/100 g; therefore, its use in preparing the porridge-like product should increase its value.

Although the condensed milk contributes 0.2 mg/100 g of iron, the values of iron fell to 0.7 and 0.6 mg/100 g, respectively. A decrease in the values of iron must take into account the dilution effect. Increasing the volume of the formulation affects the proportions of elements incorporated. Consequently, the amount of iron present is the same but in different proportions.

Among the many factors influencing the degradative mechanisms, ascorbic acid may be mentioned in temperature, salt concentration, sugar, pH, oxygen, enzymes, and metal catalysts. The cocoyam was subjected to various operations such as manual peeling, grinding, and cooking (Figure 1), which thus increased the contact surface degradation agents (oxygen, light, and temperature), therefore, is expected to be a decrease in the amounts of ascorbic acid present in both formulations. It may show that reduced values (6.7 and 5.4 mg/100 g) were reported concerning the two formulations.

The newly developed products meet quality specifications for the evaluated microbiological contaminants, as reported in the NC 585 (2013) for a standard pap-like product intended for infant consumption, where values of 4 log units specified for mesophilic microorganisms and < 3 log units for total coliforms, values for which the food does not pose a

Table 4. Quantitative descriptive analysis of the cocoyam log formulas

Formulation	Sensory attributes							
	Color	Odor	Residual taste	Sweetness	Flavor	Viscosity	Texture	Overall quality
1	9 (3)	2 (2)	11 (2)	12 (1) a	10 (2)	13 (1) a	11 (2) a	11 (2) a
2	9 (2)	11 (2)	12 (1)	8 (3) b	10 (3)	6 (3) b	7 (3) b	10 (2) a

Mean (Standard deviation); n= 10.

Different letters indicate significant differences ($p \leq 0.05$).

risk to consumer health.

The QDA results shown in Table 4 were based on comparing the two formulations. It is reported that for the parameters of color, odor, and flavor aftertaste, there was no significant difference ($p \leq 0.05$), whereas sweetness, viscosity, texture, and overall quality showed significant differences ($p \leq 0.05$). There was a big difference between texture, viscosity, and sweetness attributes. This difference could be due to the difference between the formulations (Table 1).

It can be seen that formulation 2 was more diluted by adding more water and was correctly perceived by the judges. The difference in viscosity is also due to the amount of water used in the formulation. Formulation 1, perceived as more viscous by judges, is supported by the least amount of water used in its preparation. Texture difference involves the grinding time at which each formulation was subjected. The time required to grind the mixture of formulation 1 was higher than that of formulation 2. The difference in the overall quality may have been a traditional pattern-based porridge-like product cocoyam product that is smooth to the palate and sweet with the addition of many spices; any variation in these parameters was detected by judges implied in his analysis of the finished product.

Table 5 shows the taste of potential consumers after evaluating the two formulations developed. There are no significant differences ($p \leq 0.05$) in terms of taste between formulations for all age groups. Notably, the last age group (66-75 years) was awarded products with a score of about 1, which corresponds to a standard of "I like." It is the only group for both formulations that gave this score. The reasons for this may be that the participants of this group are older and consume this product and have taken a liking and appreciation for him. At that time, the possibility of eating various foods was smaller; some people knew about such products. In the case of the other groups, although the formulations for the more significant food industry are similar, more food options are available, so they have not developed a more excellent taste for the product.

Table 5. Preference of Grenadian consumers by cocoyam log formulas

Formulation	Age interval (year)			
	15-20	**21-49**	**50-65**	**66-75**
1	3.3 (0.5) a	2.4 (1.6) ab	2.1 (1.5) ab	1.6 (0.5) ab
2	3.0 (1.4) a	3.5 (2.1) a	3.5 (1.7) a	1.0 (0.0) b

Mean (Standard deviation). n= 80.
1: Like very much; 7: Dislike very much.
Different letters indicate significant differences ($p \leq 0.05$).

Table 6. Microbiological behavior (log UFC g^{-1}) of the cocoyam log formulas during their storage (n= 3)

Formulation	Time (d)	Total aerobic bacteria	Coliform bacteria	Fungi and yeast
1	0	4	1.4	1
	14	6	2.8	3
	28	7	5.6	4
	42	>7	>6	>6
	56	>7	>6	>6
	70	>7	>6	>6
2	0	3	1	1
	14	5	2	3
	28	7	4.8	4
	42	>7	>6	>6
	56	>7	>6	>6
	70	>7	>6	>6

Table 6 shows the behavior of some microorganisms during storage. It can be seen that in both products, from day 42, there was an increase in the total count of aerobic mesophilic bacteria, total coliforms, and counting fungi and yeasts, remaining constant until the end of storage. According to the NC 585 (2013) and maximum values to ensure a consumer's health, a porridge should not exceed 5 log cycles for mesophilic microorganisms and 20 log units for total co-

liforms. Growth can be by many factors. Cocoyam is food with high moisture content and carbohydrates, mainly starch (Table 3), a polysaccharide necessary for the growth of some microorganisms (Dass et al., 2022), and therefore, its presence in higher proportions provides conditions suitable for microbial growth. In addition, condensed milk and water were added, which increased both the moisture and carbohydrates.

The pH used to prepare any food product can be used as a barrier for preventing microbial growth. Most grow in a range of a pH value between 5 and 9. Few species can grow below 2 or above 10 (Fahrig, 2020). In Tables 5 and 10, it can be appreciated that both formulations reported initial pH values close to neutrality (7.27 and 6.99), which are factors that facilitate microbial growth. Microbial growth should influence the values of pH and acidity as microorganisms consume the substrate while producing a series of acids.

The presence of coliforms is related to health practices employed and the general hygiene of the place. Any deviations from Good Manufacturing Practices may have influenced the presence and then the growth of these microorganisms.

Figure 2 shows the behavior of the pH values of the two formulations based on cocoyam pap-like products during storage. A gradual decrease in pH values was observed during storage. By comparing the behavior of pH with microbial growth (Table 6), it can be seen that there is a relationship. As it grows, the number of microorganisms' pH decreases, with a tendency to increase in the case of acid values. This behavior is because the microorganisms consumed the substrate and produced aldehydes and ketones, then converted to acids, resulting in a more acidic medium.

Figure 2 shows the behavior of the percentages of soluble solids of the two formulations based on a cocoyam porridge-like product during storage. The formulations presented in Table 1 also bring condensed milk added sugars. According to NC 362 (2004), porridge must have a soluble solid content of not more than 25% and Table 3 shows that the formulations met this criterion. A gradual decrease of soluble solids was observed in both formulations, which may have been related to microbial growth using substrate consumption and the sugars in the food.

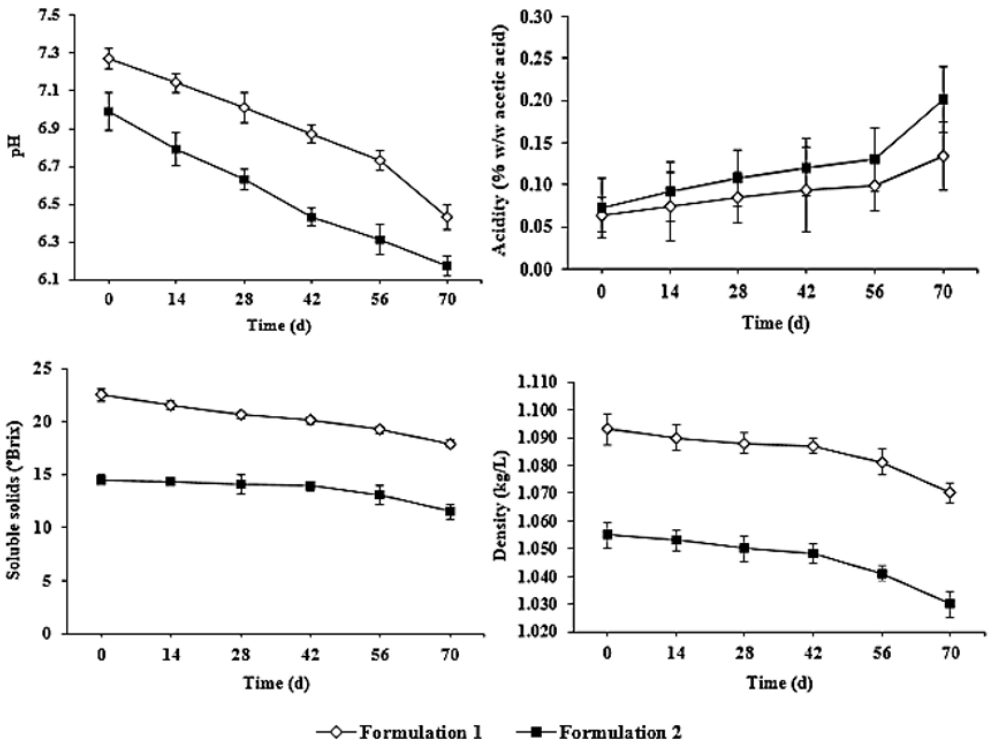

Figure 2. Behavior of the physicochemical parameters of the cocoyam log formulas during their storage. Error bars indicate standard deviation (n= 3).

Figure 2 shows the behavior of the density of the formulations during storage. It is appreciated that each formulation of density itself. Formulation 1 has more cocoyam and less water than formulation 2. It can be concluded that product 1 has a higher density than the other. It also shows that each product experienced a decrease in density throughout storage. From the microbiological analysis, we can infer that an increase in microbial activity affects the density. The microorganisms present in the pap-like product consume the raw material used in the preparation. Therefore, it can be concluded that, as there is present, a microbial growth substrate decreased and, therefore, a decrease in the density of the product (Fennema, 2021).

Conclusions

Cocoyam log is a product widely accepted among Grenadian consumers, including those over 20 years old who would buy the product. Cocoyam log was developed with good quality and acceptance that complied with sanitary and physicochemical specifications established for such a product following a simple technological process, easy to elaborate in-home settings. There was no significant difference ($p \leq 0.05$) in the consumer's preference, independent of age groups about Formula 1, whereas Formula 2 was preferred ($p \leq 0.05$) by persons between the age group of 66-75 years old. The main reason for the deterioration in both formulas during storage was related to acidification associated with microbial growth.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Statement on the use of AI

The authors acknowledge the use of generative AI and AI-assisted technologies to improve the readability and clarity of the article.

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