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Coconut-based yogurt-type product and evaluation of the effect of two stabilizers on its physical and chemical properties

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ABSTRACT: Plant-based yogurt is a lactose-free alternative that aligns with sustainability trends; however, it often faces limitations related to stability and viscosity. This study evaluated the effects of two hydrocolloids (carboxymethylcellulose (CMC) and xanthan gum (XG)) combined with potato starch on the physicochemical and rheological properties of coconut-based yogurt. Twelve treatments were prepared using different concentrations of stabilizers and starch. pH, titratable acidity, water-holding capacity (WHC), viscosity, proximate composition, and microbiological quality were determined. Data were analyzed using Type III ANOVA and Tukey's test, and multivariate patterns were explored by principal component analysis (PCA). Treatments were subsequently ranked using the TOPSIS method to identify the best formulation. Significant differences were observed among treatments, with XG-based formulations showing higher viscosity and greater WHC than CMC-based formulations. PCA confirmed stabilizer type as the main source of variation, and TOPSIS ranked treatment GX_B1 as the closest to the ideal solution. Overall, xanthan gum provided superior stability compared to CMC, supporting its suitability as a stabilizer for coconut-based, plant-based yogurt products.
Keywords: plant-based foods; carboxymethylcellulose; hydrocolloids; xanthan gum.

Produto tipo iogurte à base de coco e avaliação do efeito de dois estabilizantes em suas propriedades físico-químicas

RESUMO: O iogurte vegetal é uma alternativa aos produtos sem lactose e de origem sustentável, mas apresenta limitações quanto à estabilidade e à viscosidade. O objetivo deste estudo é avaliar o efeito de dois hidrocoloides, a carboximetilcelulose (CMC) e a goma xantana (XG), com a adição de amido de batata, sobre as propriedades físico-químicas e reológicas do iogurte à base de coco. Foram formulados 12 tratamentos com diferentes concentrações de estabilizantes e de amido. Foram analisados o pH, a acidez, a capacidade de retenção de água, a viscosidade, a composição aproximada e a qualidade microbiológica. Foram realizados ANOVA do tipo III, teste de Tukey, PCA e TOPSIS para determinar o melhor tratamento. Os resultados mostraram diferenças significativas entre os tratamentos, com as formulações GX apresentando viscosidade e capacidade de retenção de água superiores às das formulações CMC. A análise de PCA confirmou que o tipo de estabilizador era o fator diferenciador, enquanto a classificação TOPSIS posicionou o tratamento GX_B1 como o melhor. Em conclusão, a goma xantana apresenta melhores resultados em termos de estabilidade do iogurte do que a CMC e consolida-se como o estabilizador mais adequado para o desenvolvimento de iogurtes de origem vegetal.
Palavras-chave: alimentos de origem vegetal; carboximetilcelulose; hidrocoloides; goma xantana.

1. INTRODUCTION

Yogurt is traditionally produced from whole milk through lactic fermentation, in which starter cultures metabolize lactose and may include microorganisms with probiotic potential (OMOSEBI et al., 2025). In some developing countries, legumes and other plant resources have been explored as substitutes for milk and dairy products to help meet protein intake needs among both young people and adults (AKOMA et al., 2020).

In recent years, plant-based alternatives have expanded rapidly, driven by their lower environmental impact and by emerging consumer demands for safe and healthy foods (SCHIANO et al., 2020). From a sustainability perspective, these products can also be fortified with fruits, extracts, or seeds to enhance quality and consumer acceptance (WANG et al., 2025). Additionally, widespread lactose intolerance remains a key factor motivating the shift away from conventional dairy products (PACHEKREPAPOL et al., 2021). Consumption of plant proteins has increased in Europe; consequently, the development of novel yogurt-like products has gained global interest, particularly as a potentially affordable alternative to dairy foods in developing regions (MONTEMURRO et al., 2021).

Currently, traditional dairy matrices are increasingly being replaced by plant-based matrices. Coconut has been used for the production of yogurt analogues due to its nutritional attributes and the presence of bioactive compounds associated with anti-inflammatory and antioxidant effects (DASZKIEWICZ et al., 2024).

Water-soluble coconut extracts have been considered suitable substrates for the development of probiotic foods (NAIBAHO et al., 2022), and the naturally high sugar, vitamin, and mineral content of coconut water may support microbial fermentation (YASMIN et al., 2025). However, plant-based systems often require formulation strategies to achieve the texture and stability expected by consumers.

Starches are an attractive option because they generally have minimal impact on sensory properties; commercial starches are widely used as additives, while tuber-derived starches remain comparatively underutilized despite their functional contributions to physicochemical characteristics across diverse foods (BUSTOS et al., 2019). Likewise, hydrocolloids are commonly applied as thickeners and stabilizers, helping control syneresis and reduce structural defects, thereby improving product appeal (Saleh et al., 2020) and enhancing the texture and acceptance of plant-based products (SIM et al., 2020).

Despite growing demand, plant-based matrices still present challenges related to stability and texture consistency when compared with dairy yogurts (MOSS et al., 2023). These limitations justify the search for strategies that improve product structure through the incorporation of hydrocolloids and starches, which can act as supportive agents to reduce syneresis and strengthen the stability of the final product. Therefore, the main objective of this study was to evaluate the effects of two hydrocolloids, in combination with potato starch, on the physicochemical properties and stability of coconut-based yogurt.

2. MATERIAL AND METHODS

2.1. Preparation of coconut milk

Coconut milk was prepared from ripe coconut pulp. The pulp was grated and homogenized in a blender with water at a 1:6 (pulp:water, w/v) ratio. The mixture was then filtered through a cloth and pasteurized at 75 °C for 15 min.

2.2. Yogurt production

To produce yogurt-like products, coconut milk was formulated with potato starch, sucrose (sweetener), and the stabilizers xanthan gum (GX) and carboxymethylcellulose (CMC). The mixture was inoculated with *Lactobacillus bulgaricus* and incubated at 42 °C for 12 h.

Preliminary trials were conducted to define the levels of potato starch, xanthan gum, and CMC. A total of twelve formulations were prepared and incubated until reaching pH 4.0–4.2. Fermentation was stopped by refrigeration, and samples were stored at 4 °C until analysis. Treatments were defined as follows:

Table 1. Composition of the treatments evaluated based on the concentration of the stabilizers CMC, xanthan gum, and potato starch.
Tabela 1. Composição dos tratamentos avaliados de acordo com as concentrações dos estabilizantes CMC, goma xantana e amido de batata.

Treatments	Code	Coconut milk base (%) *	Sucrose (%) **	Potato starch (%) **	Xanthan Gum (%) **	CMC (%) **	Lactic acid bacteria (%) **
1	CMC_A1	100	6.0	0.5	—	2.2	0.004
2	CMC_A2	100	6.0	0.9	—	2.2	0.004
3	CMC_A3	100	6.0	1.3	—	2.2	0.004
4	CMC_B1	100	6.0	0.5	—	2.8	0.004
5	CMC_B2	100	6.0	0.9	—	2.8	0.004
6	CMC_B3	100	6.0	1.3	—	2.8	0.004
7	GX_A1	100	6.0	0.5	1.6	—	0.004
8	GX_A2	100	6.0	0.9	1.6	—	0.004
9	GX_A3	100	6.0	1.3	1.6	—	0.004
10	GX_B1	100	6.0	0.5	2.2	—	0.004
11	GX_B2	100	6.0	0.9	2.2	—	0.004
12	GX_B3	100	6.0	1.3	2.2	—	0.004

*The coconut milk base used in all treatments was prepared by standard homogenization of 60 g of coconut pulp in 1 liter of water.
**The percentages of the additional ingredients (sucrose, starch, hydrocolloids, and inoculum) are expressed relative to the total weight/volume of the base coconut milk used (taken as the 100% reference for each treatment).
*A base de leite de coco utilizada em todos os tratamentos foi preparada mediante a homogeneização padrão de 60 g de polpa de coco em 1 litro de água.
**As porcentagens dos ingredientes adicionais (sacarose, amido, hidrocoloides e inóculo) são expressas em relação ao peso/volume total da base de leite de coco utilizada (tomada como referência de 100% para cada tratamento).

2.3. Physico-chemical evaluation

2.3.1. Determination of pH and titratable acidity

During fermentation, pH and total titratable acidity were determined according to standard AOAC methods (pH: 943.02; titratable acidity: 947.05). The pH was measured using a portable pH meter (PH8500-DP). Titratable acidity was determined by preparing a mixture of yogurt and distilled water, adding phenolphthalein as an indicator, and titrating with standardized 0.1 M NaOH to the first persistent color change (pale pink).

2.3.2. Determination of water holding capacity (WHC)

Water-holding capacity (WHC), expressed as resistance to syneresis, was evaluated by centrifugation according to the Kessler technique (1998). Samples were centrifuged at 5000 rpm for 20 min, and the expelled aqueous phase was collected and weighed. WHC was calculated using Equation (1)

$$WHC\% = \left(1 - \frac{\text{M aqueous phase}}{\text{M inicial sample}}\right) x\ 100 \qquad (01)$$

where: WHC %: water retention capacity; M aqueous phase: mass of the liquid separated after centrifugation (g); M Initial sample mass: mass of plant-based yogurt before centrifugation (g).

2.4. Rheological analysis

The rheological behavior was evaluated by determining the apparent viscosity at different rotation speeds of 50, 100, 180, and 200 rpm. A Brookfield viscometer (model DV II +

Viscosimeter) with an LV-4 spindle was used. Since this system does not allow for the direct measurement of shear rate and shear stress, no fitting of rheological models such as the Power Law or Herschel-Bulkley model was performed. Therefore, the comparison between treatments was carried out through descriptive analysis of the apparent viscosity curves, as shown in Figure 3.

2.5. Statistical analysis

A 2x2x3 factorial design was used, with the following factors: type of stabilizer (CMC, xanthan gum), stabilizer level (A = 2.2% and B = 2.8%), and starch concentration (1 = 0.5%, 2 = 0.9%, and 3 = 1.3%), while also considering the interactions between the factors, in accordance with the treatment composition presented in Table 1. Twelve treatments were evaluated, each with two independent replicates, resulting in a total of 24 experimental units. The base coconut milk was prepared in a single batch and subsequently distributed into 24 individual 1-liter containers. The corresponding amounts of ingredients were added independently to each container according to the assigned treatment; fermentation was carried out independently. Each 1-liter container of prepared yogurt constituted one experimental unit (Figure 1).


a)


b)

Figure 1. Experimental units used in the study. (a) Distribution of the 24 independent experimental units corresponding to the 12 treatments evaluated, with two biological replicates per treatment. (b) Arrangement of the experimental units during the evaluation of the physicochemical and rheological properties of coconut yogurt.
Figura 1. Unidades experimentais utilizadas no estudo. (a) Distribuição das 24 unidades experimentais independentes correspondentes aos 12 tratamentos avaliados, com duas réplicas biológicas por tratamento. (b) Disposição das unidades experimentais durante a avaliação das propriedades físico-químicas e reológicas do iogurte de coco.

For each response variable, a linear model was fitted that included the main effects of stabilizer type, stabilizer level, potato starch concentration, and all their interactions.

$$Y = \mu + E + C + A + E \times C + E \times A + C \times A + E \times C \times A + \varepsilon \qquad (02)$$

where: E: type of stabilizer; C: stabilizer level; A: potato starch concentration

Due to the small number of biological replicates per treatment, formal tests for normality and homogeneity of variance were not performed; therefore, the ANOVA results should be interpreted within the experimental scope of the study.

An analysis of variance (Type III ANOVA) was used, which allows for the estimation of the effect of each factor adjusted for the presence of the other factors and interactions included in the model. When significant differences were detected ($p < 0.05$), the means were compared using Tukey's test. Statistical analysis was performed using the R software (RStudio). Subsequently, principal component analysis (PCA) was applied to evaluate multivariate variability and explore relationships among the physicochemical variables. Finally, treatments were ranked using the TOPSIS multicriteria method, considering the experimental results and reference ranges previously established in the literature

2.6. Nutritional evaluation

proximate analysis was performed on the best-performing treatment, selected based on the overall results of the physicochemical and rheological analyses. Standard AOAC methods were used to determine moisture (930.15), crude protein (total N × 6.25) (955.39), crude fat (920.39), crude fiber (978.10), and ash (923.03). Total carbohydrates were calculated by difference on a dry matter basis, subtracting the percentages of crude protein, crude fat, crude fiber, and ash from the total dry matter.

2.7. Microbiological analysis:

Microbiological quality was assessed using 3M Petrifilm™ rapid plates, following AOAC methods for total coliforms and *Escherichia coli* (991.14), and for molds and yeasts (997.02). The analysis was conducted only on formulation GX_B1, which was selected using the TOPSIS method because it exhibited the best performance among the physicochemical and rheological variables evaluated, since the objective was to verify compliance with the microbiological criteria. Results were interpreted by comparison with the Ecuadorian technical standard NTE INEN 2395, used as a reference due to the absence of a specific national standard for fermented plant-based products.

3. RESULTS

3.1. Physico-chemical parameters of coconut yogurt

Table 2 shows the mean and standard deviation of pH, titratable acidity, and water holding capacity (WHC) of the formulated coconut yogurt treatments.

The formulations containing carboxymethylcellulose (CMC) showed no significant differences in pH among treatments ($p<0.05$). Likewise, treatments formulated with xanthan gum (XG) did not differ statistically from each other. In contrast, a significant difference in pH was observed between the CMC- and XG-based groups ($p>0.05$).

For titratable acidity, significant differences were detected among treatments ($p<0.05$). Treatments labeled with the letter "b" exhibited significantly higher acidity than those labeled with the letter "a".

Regarding water-holding capacity (WHC), highly significant differences were found among treatments ($p<0.05$). Treatments assigned the letter "a" presented the highest WHC values, whereas those labeled "c" showed the lowest WHC.

Table 2. Mean and standard deviation of the physicochemical parameters of the coconut yogurt formulations.
Tabela 2. Média e desvio padrão dos parâmetros físico-químicos das formulações do iogurte de coco.

Treatments	pH (mean ± DE)	Acidity (°D) (mean ± DE)	WHC (%) (mean ± DE)
CMC_A1	4.23 ± 0.02^{a}	45.1 ± 1.2^{a}	30.5 ± 2.1^{c}
CMC_A2	4.24 ± 0.03^{a}	47.3 ± 1.1^{a}	42.7 ± 2.5^{b}
CMC_A3	4.25 ± 0.02^{a}	49.6 ± 1.4^{b}	48.6 ± 3.0^{b}
CMC_B1	4.24 ± 0.02^{a}	46.2 ± 1.3^{a}	59.8 ± 2.2^{a}
CMC_B2	4.25 ± 0.03^{a}	47.9 ± 1.2^{b}	50.4 ± 2.7^{b}
CMC_B3	4.26 ± 0.02^{a}	44.8 ± 1.0^{a}	43.2 ± 2.4^{b}
GX_A1	4.10 ± 0.01^{b}	48.7 ± 1.3^{b}	88.6 ± 2.8^{a}
GX_A2	4.10 ± 0.02^{b}	49.1 ± 1.4^{b}	86.3 ± 2.5^{a}
GX_A3	4.09 ± 0.01^{b}	47.8 ± 1.2^{b}	87.1 ± 2.6^{a}
GX_B1	4.11 ± 0.02^{b}	48.2 ± 1.3^{b}	96.8 ± 3.1^{a}
GX_B2	4.09 ± 0.01^{b}	47.6 ± 1.1^{b}	97.3 ± 2.9^{a}
GX_B3	4.11 ± 0.02^{b}	49.0 ± 1.5^{b}	98.1 ± 3.0^{a}

The columns indicate the mean + SD (standard deviation) for each physical parameter. Different letters in the same column indicate significant differences according to the Tukey test ($p<0.05$).
As colunas indicam a média + DP (desvio-padrão) para cada parâmetro físico. Letras diferentes na mesma coluna indicam diferenças significativas de acordo com o teste de Tukey ($p < 0,05$).

3.2. Comparison of physico-chemical parameters with reference values

Most treatments presented pH values within the reference range (Figure 2). Formulations containing CMC tended to show slightly higher pH values within the acceptable interval, whereas XG-based formulations exhibited pH values closer to the lower limit of the range.

Regarding titratable acidity, both CMC- and XG-based treatments were outside the range established by international standards. Nevertheless, XG formulations showed slightly higher acidity values than CMC formulations.

Marked differences were observed in WHC depending on the stabilizer used. CMC formulations displayed WHC values below the reference range, reaching a maximum of 60%, while XG formulations exceeded 80%, falling within commonly reported ranges for commercial dairy and plant-based yogurts.

3.3. Rheological Behavior

The viscosity vs. shear rate curve shows that viscosity decreased as shear rate increased, demonstrating typical non-Newtonian behavior in yogurts.

Figure 3 shows that the formulations containing xanthan gum exhibited higher viscosity values at low shear rates compared to the formulations containing CMC. This difference was most evident in the GX_B1 and GX_B2 treatments, which had initial values approximately 44% higher than those of the CMC treatments.

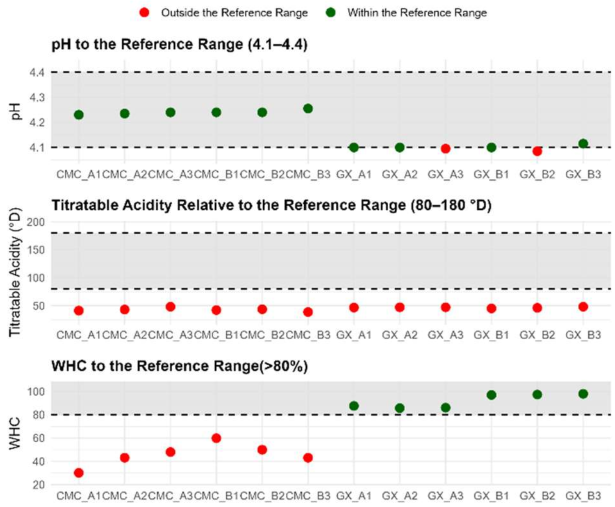

Figure 2. Comparison of pH, titratable acidity, and water-holding capacity (WHC) with reference values. Figura 2. Comparação do pH, acidez titulável e capacidade de retenção de água (WHC) em relação aos valores de referência.
Figure 2. Comparison of pH, titratable acidity, and water-holding capacity (WHC) across all treatments formulated with carboxymethylcellulose (CMC) or Xanthan gum (XG), relative to reference ranges established for commercial yogurts.

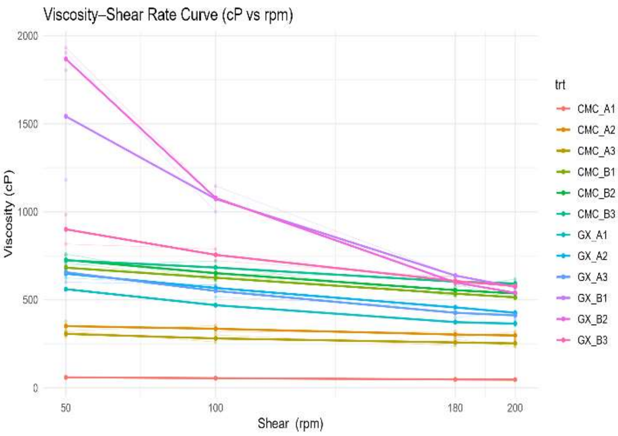

Figure 3. Viscosity curves as a function of shear rate (rpm) for the different treatments.
Figura 3. Curvas de viscosidade em função da velocidade de cisalhamento (rpm) para os diferentes tratamentos.

3.4. Principal component analysis (PCA)

The PCA indicated that the first two principal components accounted for 92.2% of the total variance (Figure 4). Treatments formulated with CMC were primarily distributed on the negative side of principal component 1 (Dim1) and exhibited greater dispersion, whereas xanthan gum formulations clustered on the positive side of Dim1 with lower dispersion.

3.5. Ranking of treatments using TOPSIS

The classification obtained using the TOPSIS method shows that the treatments formulated with xanthan gum occupy the top positions in the ranking (Figure 5). Treatments GX_B1 and GX_B3 have the values closest to the ideal solution 1, while the treatments formulated with CMC are in the middle and lower positions.

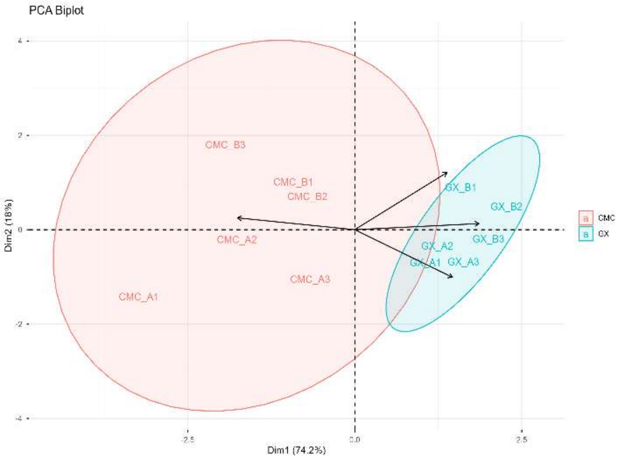

Figure 4. Principal component analysis (PCA) of treatments based on physico-chemical and rheological parameters.
Figura 4. Análise de componentes principais (PCA) dos tratamentos com base em parâmetros físico-químicos e reológicos.

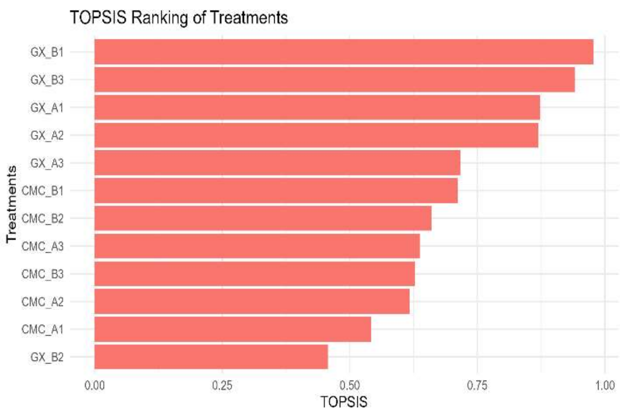

Figure 5. Ranking of coconut yogurt treatments using the TOPSIS method, considering physico-chemical and rheological parameters.
Figura 5. Classificação dos tratamentos do iogurte de coco através do método TOPSIS, considerando parâmetros físico-químicos e reológicos.

3.6. Proximal composition

The proximate composition of treatment GX_B1, identified as the best-performing formulation according to the TOPSIS ranking and the other evaluated parameters, is presented in Table 3. Overall, GX_B1 exhibited a profile consistent with plant-based yogurts, characterized by high moisture and low protein contents, as well as relatively high fat content associated with the coconut-based matrix. The ash and total carbohydrate contents reflect the contribution of added ingredients, particularly sucrose and starch, included in the formulation.

Table 3. Proximal composition (100 g) of coconut yogurt from the treatment GX_B1.
Tabela 3. Composição proximal (100 g) do iogurte de coco do tratamento GX_B1.

Parameter	Content (g/100g)
Moisture	78.55
Protein	1.58
Grasa	5.92
Fiber	0.53
Ash	0.67
Total carbohydrates	12.57

3.7. Microbiological quality

The microbiological results for treatment GX_B1 indicated the absence of total coliforms and a mold and yeast count of $<10^2$ CFU/ g, reflecting adequate hygienic conditions during product processing (Table 4).

Table 4. Microbiological count of formulation GX_B1.
Tabela 4. Contagem microbiológica da formulação GX_B1

Microorganism	Unit	Results (GX_B1)
Total coliforms	UFC/mL	Absence
Molds and yeasts	UFC/g	$< 10^2$

4. DISCUSSION

The results of this study indicate that the type of hydrocolloid significantly influences the physicochemical, rheological, and stability attributes of coconut-based yogurt. Regarding pH, all treatments remained within the typical range reported for yogurt (4.1–4.4), suggesting adequate acidification and proper gel development. This trend is consistent with (Ibáñez, 2025), who notes that pH values within this interval reflect the appropriate progression of the fermentation process. Similarly, Greis et al. (2022) reported stable pH values in CMC-based formulations, whereas xanthan gum systems may show slight variation, supporting the notion that the stabilizer type can modulate product acidification, consistent with the differences observed here.

In terms of titratable acidity, both CMC- and xanthan gum–based formulations showed values below the minimum established for yogurt (60 °D) by the Codex Alimentarius Commission. This observed behavior can be attributed not only to the fact that the coconut matrix is lactose-free, but also to the limited content of fermentable carbohydrates in coconut milk compared to animal milk. Although sucrose was added to promote fermentation, the utilization of this sugar by lactic acid cultures depends on the metabolic capacity of the strains used. Consequently, the lower lactic acid production may have influenced the development of a gel structure that is less dependent on acidification and more supported by the action of hydrocolloids and potato starch. These findings agree with Grasso et al. (2020), who reported titratable acidity values of approximately 36 °D in coconut yogurt. Moreover, Aguirre-García et al. (2024) emphasize that lactic fermentation is a complex biochemical process dependent on the type and availability of carbohydrates; therefore, lower organic acid production is commonly observed in plant matrices, which explains the results obtained.

With respect to water-holding capacity (WHC), highly significant differences were detected among treatments, with xanthan gum formulations standing out by reaching values above 80%, compared with CMC treatments, whose maximum values were around 60%. Grasso et al. (2020) attribute reduced WHC in low-protein products to limited gel-forming capacity and a higher proportion of free water. Unlike conventional yogurt, where gel formation depends on the aggregation of casein micelles during acidification, the low protein concentration in coconut milk limits the formation of a protein network.

Under these conditions, it is reasonable to assume that structural stability depends to a greater extent on the interaction between hydrocolloids and potato starch, which could contribute to the good performance observed in formulations containing xanthan gum. However, this interpretation is based on evidence reported in the literature and was not corroborated in this study, as no microstructural analysis was performed. In contrast, the elevated WHC values achieved with xanthan gum fall within ranges reported for commercial dairy and plant-based yogurts (NGUYEN et al., 2025). In addition, Raikos et al. (2020) indicate that the high fat content of coconut, in combination with hydrocolloids, can positively contribute to gel stability. These outcomes align with Sangkam et al. (2023), who found that the addition of xanthan gum has been associated with lower syneresis and higher water retention due to its ability to promote the immobilization of the aqueous phase within the yogurt matrix. This behavior is consistent with the higher water-holding capacity values observed in this study.

Rheological results showed that all formulations exhibited pseudoplastic (non-Newtonian) behavior, characterized by decreasing apparent viscosity as shear rate increased. This behavior is consistent with that of Greis et al. (2022), who reported shear-thinning in both dairy and plant-based yogurt systems. Likewise, Vicent (2024) reported a flow behavior index below 1.00, which is consistent with the response observed in this product. Xanthan gum formulations, particularly GX_B1 and GX_B2, showed higher apparent viscosity at low shear rates than CMC-based formulations. This could be associated with greater interaction between xanthan gum, potato starch, and the components of the coconut matrix, as suggested by (MARLAPATI et al., 2024). However, these interactions were not directly evaluated in this study. In line with this, Saleh et al. (2020) recommend combining xanthan gum with potato starch to maintain gel firmness during storage. The viscosity values obtained fall within ranges reported for dairy and plant-based yogurts (1.6–3.3 Pa·s). Błaszak et al. (2025) support the structural similarity of the best-performing treatments to commercial products. Although the viscosity curves made it possible to identify the pseudoplastic behavior of the formulations, this study did not include the fitting of rheological models, since the equipment provides measurements of apparent viscosity but not values for shear rate or stress, which made it impossible to estimate the consistency index (k) and the flow behavior index (n).

Principal component analysis (PCA) integrated the physicochemical and rheological variables and explained 92.2% of the total variability, indicating that the first two components captured most of the multivariate information in the dataset. PCA also clearly discriminated against treatments according to stabilizer type, with xanthan gum emerging as a primary source of variation, even relative to starch concentration. This behavior agrees with Grasso et al. (2020), who highlight that the hydrocolloid largely defines the structure and stability of plant-based yogurts. The strong correlation observed between the xanthan gum formulations and the viscosity and water-holding capacity parameters is consistent with the experimental results obtained.

Classification using the TOPSIS method allowed for the simultaneous integration of the evaluated physicochemical and rheological variables, identifying treatments GX_B1 and GX_B3 as the closest to the ideal solution, with GX_B1 being the best-performing formulation under the experimental conditions and based on the variables analyzed in this study. Madanchian; Taherdoost (2023) emphasize that TOPSIS is an effective tool for integrating multiple criteria in the evaluation of food product quality. Likewise, Zhang et al. (2022) reported that the interaction between xanthan gum and starch has been associated with the formation of a more efficient three-dimensional network for water retention. This mechanism proposed in the literature is consistent with the better performance observed in formulations containing xanthan gum; however, it was not directly evaluated in this study through microstructural analysis.

Although the multi-criteria analysis identified GX_B1 as the optimal formulation considering the physicochemical and rheological variables evaluated, these results should be interpreted within the scope of the present study. Sensory analysis, storage stability, microbiological behavior, lactic culture viability, and monitoring of phase separation during shelf life were not included. Therefore, the superiority of GX_B1 is limited to the experimental conditions and the criteria evaluated. In future studies, it is recommended that these aspects be incorporated to conduct a comprehensive evaluation of the product's quality and acceptance.

Regarding the proximal composition of the formulation (GX_B1), which was selected because it performed better among the evaluated variables. Moisture content was close to the range reported for yogurts (80–82%) (Asante et al., 2025), while the low protein content aligns with values reported for similar products (1.27–2.80%) (THURAISINGAM et al., 2023). Aydar et al. (2020), note that, in the absence of a strong protein network, structural stability has been linked to the synergy between starch and hydrocolloids, which could explain the good performance of GX_B1. Fat and ash contents were within the ranges (2.3–7.9%) and (0.7–1.3%), respectively, reported by Sim et al. (2020). Likewise, total carbohydrate values were consistent with those reported for plant-based yogurts (9.0–12.8%) (MARLAPATI et al., 2024).

Finally, the microbiological evaluation was limited to the formulation selected using the TOPSIS method (GX_B1); therefore, it is not possible to extrapolate these results to the other treatments, meeting the limits established in the Ecuadorian technical standard NTE INEN 2395 for fermented milks, which was used as a reference in the absence of specific criteria for fermented plant-based products. These findings are consistent with Zhang et al. (2022), who highlight that adequate lactic fermentation and the implementation of good manufacturing practices contribute to microbiological stability and food safety in plant-based yogurts.

An additional limitation of this study was the absence of a control treatment without hydrocolloids or potato starch. Consequently, the results allow for a comparison of the relative performance of carboxymethylcellulose and xanthan gum at different concentrations, but do not quantify the absolute effect of these ingredients relative to a base formulation. During preliminary trials, rapid phase separation was observed in the formulation without hydrocolloids, which demonstrated its low physical stability and led the study to focus on comparing stabilizing systems.

5. CONCLUSIONS

The results of this study indicate that incorporating hydrocolloids into coconut-based yogurt significantly affects the product's physicochemical and rheological properties and its stability, thereby meeting the proposed objective. The stabilizer type elicited distinct responses within the plant-based matrix, which confirms its role as a determining factor in the experimental conditions evaluated. These results should not be extrapolated to other plant-based formulations or different storage conditions without prior studies.

Treatment pH values remained within the typical yogurt range, whereas titratable acidity was low in all formulations, suggesting limited acid development associated with the coconut matrix and the absence of lactose.

Formulations containing xanthan gum showed higher water-holding capacity, improved gel stability, and a higher apparent viscosity than the formulations made with carboxymethylcellulose (CMC), showing better performance in the physicochemical and rheological variables evaluated. In addition, all formulations exhibited pseudoplastic non-Newtonian behavior, which is characteristic of this type of product.

Proximate analysis showed that coconut yogurt composition reflects the characteristics of the plant-based raw material, with moisture and fat contents as prominent components, and without meaningful variation attributable to hydrocolloid type. The microbiological evaluation conducted on the selected formulation, GX_B1, demonstrated compliance with the requirements established for this type of product, confirming its safety under the manufacturing conditions used.

Overall, the results suggest that the GX_B1 formulation performed best under the experimental conditions of this study. However, these results should be interpreted within the scope of this research, as aspects such as sensory acceptance, storage stability, and the microbiological behavior of all formulations were not evaluated.

It is recommended that future research incorporate control formulations, microstructural analyses, sensory evaluation, shelf-life studies, and fitting to rheological models, in order to obtain a more comprehensive characterization of the behavior of coconut-based yogurts.

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