Polo del Conocimiento
Pol. Con. (Edición núm. 85) Vol. 8, No 8
Agosto 2023, pp. 1628-1646
ISSN: 2550 - 682X
DOI: 10.23857/pc.v8i8

Influencia de estabilizantes en la calidad fisicoquímica y sensorial del jarabe de plátano/maracuyá

Influence of stabilizers on the physicochemical and sensory quality of banana/passion fruit syrup

Influência de estabilizantes na qualidade físico-química e sensorial de calda de banana/maracujá

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Ciencias Técnica y Aplicadas
Artículo de Investigación

*** Recibido:** 17 de junio de 2023 ***Aceptado:** 22 de julio de 2023 *** Publicado:** 13 de agosto de 2023

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Resumen

El objetivo de esta investigación fue evaluar la influencia de la variedad de fruta y el tipo de estabilizadores en las características fisicoquímicas y sensoriales del jarabe de banano y maracuyá. Se estudiaron las características físicas y químicas de las materias primas, incluyendo las variedades de frutas Cavendish Valery y Gros Michel, y los estabilizadores goma xantán y carboximetilcelulosa (CMC). Para determinar las diferencias estadísticas, se utilizó un diseño factorial 2^2. Las variables de respuesta fueron «Brix», «viscosidad» y «aceptación del consumidor». Se realizó un análisis de varianza multifactorial para determinar el grado de los efectos sobre las variables de respuesta. Una vez obtenidos los resultados del análisis estadístico, se llevaron a cabo pruebas fisicoquímicas en la formulación determinada como la mejor. Los resultados de las pruebas fueron 2,18% de ceniza, 64,30 °Brix, 0,37% de acidez (en términos de ácido cítrico), 4,04 de pH, 29,01% de humedad, 1,27 de densidad relativa, 23,7% de azúcares reductores totales, 11,9% de fructosa, 11,8% de glucosa, 35,4% de sacarosa, 5405,2 cp de viscosidad y 400-470 nm en cuanto al color. La viscosidad no se vio afectada por el tipo de estabilizador o la variedad de plátano, sin embargo, el estabilizador utilizado influye en los grados Brix.

Palabras claves: Influencia; estabilizantes; fisicoquímica; plátano/maracuyá.

Abstract

The objective of this research was to evaluate the influence of the variety of fruit and the type of stabilizers on the physicochemical and sensory characteristics of banana and passion fruit syrup. The physical and chemical characteristics of the raw materials were studied, including the Cavendish Valery and Gros Michel fruit varieties, and the stabilizers xanthan gum and carboxymethylcellulose (CMC). To determine the statistical differences, a 22 factorial design was used. The response variables were «Brix», «viscosity» and «consumer acceptance». A multivariate analysis of variance was performed to determine the degree of effects on the response variables. Once the results of the statistical analysis were obtained, physicochemical tests were carried out on the formulation determined to be the best. The test results were 2.18% ash, 64.30 °Brix, 0.37% acidity (in terms of citric acid), 4.04 pH, 29.01% moisture, 1.27 relative density, 23.7% total reducing sugars, 11.9% fructose, 11.8% glucose, 35.4% sucrose, 5405.2 cp viscosity, and 400-470 nm for color. The viscosity was not affected by the type of stabilizer or the variety of banana, however, the stabilizer used influences the Brix degrees.

Keywords: Influence; stabilizers; physical chemistry; banana/passion fruit

Resumo

O objetivo desta pesquisa foi avaliar a influência da variedade da fruta e do tipo de estabilizantes nas características físico-químicas e sensoriais de banana e calda de maracujá. Foram estudadas as características físicas e químicas das matérias-primas, incluindo as variedades de frutas Cavendish Valery e Gros Michel, e os estabilizantes goma xantana e carboximetilcelulose (CMC). Para determinar as diferenças estatísticas, foi utilizado um planejamento fatorial 22. As variáveis de resposta foram «Brix», «viscosidade» e «aceitação do consumidor». Uma análise multivariada de variância foi realizada para determinar o grau de efeitos nas variáveis de resposta. Obtidos os resultados da análise estatística, foram realizados testes físico-químicos na formulação considerada a melhor. Os resultados do teste foram 2,18% de cinzas, 64,30 °Brix, 0,37% de acidez (em termos de ácido cítrico), 4,04 pH, 29,01% de umidade, 1,27 de densidade relativa, 23,7% de açúcares redutores totais, 11,9% de frutose, 11,8% de glicose, 35,4% sacarose, viscosidade de 5405,2 cp e 400-470 nm para cor. A viscosidade não foi afetada pelo tipo de estabilizante e nem pela variedade de banana, entretanto, o estabilizante utilizado influencia nos graus Brix.

Palavras-chave: Influência; estabilizadores; química Física; banana/ maracujá.

Introduction

Syrups are sweet condiment sauces obtained, generally, by dissolving sugar in boiling water and adding flavoring agents (Bellaera et al., 2018). Syrups are commonly used in confectionery, bakery fillings, and the production of fizz drinks (Manzocco, 2002). Ingredients commonly found in syrup formulations include water, sugar, colorants, acidulants, preservatives, and stabilizers. Fruit juice can also be used as a base for manufacturing syrups by removing the water content partially through heat treatments concentrating the sugar content to around 65% - 90% and increasing their viscosity (Zargaraan et al., 2016). Some fruits such as Ecuadorian bananas are suitable ingredients for syrups since when reaching ripeness stages, pleasant flavors and desirable organoleptic characteristics rise. Regarding their nutritional properties, bananas provide considerable amounts of magnesium, iron, phosphorus, calcium, potassium, vitamin B, and vitamin C. Banana cultivation is a significant factor in the Ecuadorian economy; circa 196,673 hectares are dedicated to banana plantations, of which 186,225 hectares are currently exploited (Criollo Feijóo et al., 2020; Seraquive, 2017). The production of surpluses of lower commercial value is a common issue, although their nutritional value remains intact (Bonilla-Leiva & González-Carbajal, 2000). Around 30% of organic dessert bananas is rejected (Criollo Feijóo et al., 2020). Organic bananas are prone to be rejected for export as they usually do not comply with the requirements established in the Ecuadorian standard NTE INEN 2801-2013 due to cultivation and production practices (Medranda & Soledispa, 2019). Other fruit with an interesting cultivation profile is Passion fruit, a common source in the production of juices and concentrated pulps. Weather conditions in Ecuador are favorable to enhance the production and industrialization of Passion fruit (Tigrero González et al., 2016). Local germplasms of Passion fruit (“Criollo” variety) are grown in farms and reach a 7t ha^{-1} yield. On average, an individual Passion fruit weighs 93 g and the thickness of its peel is around 5 mm (Viera et al., 2022). Alongside fruits, some stabilizers, including certain hydrocolloids, provide desired characteristics to syrups; among these, gums are polymers that form viscous dispersions during gelation when mixed with water at certain proportion, depending on the gum (Quiroz et al., 2019). Gums are used in the food industry to modify the rheology of food systems, i.e., their flow behavior, viscosity, and solid features, while modifying certain sensory characteristics (Angioloni, 2013); in the case of innovative formulations to manufacture syrups, these features need to be proven. The objective of this work is to study the influence of the type of banana (*Musa paradisiaca*) and the type of stabilizer (gum) in the characteristics of syrups including Passion fruit (*Passiflora edulis*) to determine the best combination of factors resulting in the best final product.

Methodology

Preparation of raw materials

Non-exportable bananas were sourced from an organic farm in Tenguel, Guayas province, Ecuador. Two varieties of bananas, Cavendish Valery and Gros Michel, were used. Bananas at ripeness stage 6-7, at a ripeness index and peeling color described in the von Loesecke scale (Torres et al. 2012; Torres et al., 2013) were selected. The passion fruits were obtained from a farm in Camilo Ponce Enríquez, Azuay, Ecuador. The bananas were washed and disinfected by soaking in a quaternary ammonium solution (1.5 ppm) for 5 minutes, then were peeled, chopped, and blended. Passion fruits were cut transversely to extract their pulp which was sieved to separate the juice from the seeds.

Characterization of raw materials

The ash content of bananas of the 2 varieties studied, as well as in Passion fruit, was determined after AOAC 942.05/90 method. The moisture content in samples of each fruit was determined via thermogravimetry (Arrázola-Paternina et al., 2013). The determination of soluble solids was carried out in 10 g of banana pulp (for each variety) and 10 mL of Passion fruit juice, respectively, with a a digital refractometer HI 96801 (Hanna Instruments, Woonsocket, Rhode Island, United States) according to the AOAC 932.12/90 method (Arrázola-Paternina et al., 2013; Quiceno et al., 2014). The pH determination was carried out in the filtered blended mixture of 30 g of banana and 90 mL of distilled water for 2 minutes was used; in the case of Passion fruit, 75 g of juice was utilized. The pH value on each case was measured in triplicate with a multiparametric potentiometer 900P (Bante Instruments Co., Ltd., Shanghai, China) (Arrázola-Paternina et al., 2013). The titratable acidity was determined after AOAC 942.15. For banana, 30 g of a blended sample of banana were mixed with 90 mL of distilled water; this mixture was filtered after 20 minutes of stand, then 25 mL of distilled water was added. For the passion fruit, a 50 mL of pure juice sample was prepared. The samples were titrated with NaOH 0.1 N; phenolphthalein was used as an indicator (Martínez-Hernández & Bermúdez-Camacho, 2016). All tests were performed in triplicate.

Product formulation

A preliminary formulation, developed and used in this study to evaluate the characteristics of the resulting product, is outlined in Table 1. The parameters here depicted as “banana” and “stabilizer” change accordingly to the factor evaluated in the resulted treatment.

Table 1. Banana/passion fruit working formulation.

Ingredients	*Percentage (%)*

Water	40
Banana	40
Sugar	15.16
Passion fruit	4.24
Stabilizer	0.4
Preservative	0.1
Citric acid	0.1

Experimental design

A factorial design was employed to observe the influence of banana variety and stabilizer type on the physicochemical attributes of syrups. The statistical analysis was carried out using Statgraphics Centurion XVI.II (Statgraphics Technologies, Inc., The Plains, United States) statistical package. A multifactorial analysis was performed with one replicate. The experimental design and corresponding treatments are summarized in Table 2. The response variables evaluated were "sensory acceptance," "viscosity," and "soluble solids content." The syrups were prepared following the method outlined by Duarte-Gonzales et al. (2018).

Table 2. Variables studied and levels proposed in syrup formulations.

Variables or factors	*Levels*
Banana type	Cavendish Valery
	Gros Michel
Stabilizer type	Carboxymethylcellulose (CMC)
	Xanthan gum

Sensory evaluation

To determine the optimal formulation, a sensory evaluation was conducted on the four resulting formulations and their respective replicates, which resulted in a total of eight trials. The panel of evaluators consisted of 20 semi-trained judges of different ages and genders. A quantitative analysis was performed to assess the sensory acceptance of the formulations using a 5-point verbal hedonic scale, ranging from 5 ("I like it very much") to 1 ("I dislike it very much"), as described by Hernández (2005). The panelists were instructed to provide feedback on their level of satisfaction with the product evaluated.

Physicochemical evaluation of syrups

Soluble solids in the syrups were quantified using refractometric techniques. The viscosity of each treatment was determined using a dial reading viscometer (Brookfield, Middleboro, United States) at 20 rpm and 21°C. The results were reported in Pa.s and subsequently converted to centipoises (10^{-3} Pa-s). Ash content was determined according to the Mexican standard NMX-F-066-S (1978) by calcination in a furnace at 550 °C. Upon complete calcination, the crucible was allowed to cool down and the final weights were recorded. The acidity percentage was determined via titration with NaOH 0.1 N following the method described by Periago et al. (2016). The amount of reducing sugars was determined by high-performance liquid chromatography (HPLC), following the method described by Guerra & Ortega (2006) and Periago et al. (2016). 1 g of sample was dissolved in distilled water and filtered through 0.2 mm filter paper. The filtrate was then injected into the HPLC aminospheri column (220 mm x 4.6 mm). An acetonitrile mobile phase containing 0.01% tetraethylene-pentamine and water (70:30, v/v) was used to elute the sample, starting at a flow rate of 1.5 mL/min. The results were obtained from the refractive index detector integrated control system. Color patterns of the passion fruit-banana syrups were measured using UV-visible spectrophotometry, which measures the interaction of molecules or atoms with electromagnetic radiation, with the wavelength ranges extending into the infrared region (Barba Álvarez & Naranjo de la Vera, 2021). Sensory analysis was performed using a combination of profile and categorical scale tests to determine the best formulation among the samples. Sensory acceptance was assessed using a multifactorial ANOVA to detect significant differences in the sensory response of the panelists. A 3-point scale was used to score the samples, where the sensory acceptance was represented as 1 (“low”), 2 (“moderate”), and 3 (“high”).

Results

The results obtained for the chemical parameters evaluated in both banana species, Gros Michel and Cavendish Valery, are presented in Table 2. The chemical parameters found for Passion fruit are shown in Table 3.

Table 2 Results of the chemical analysis in Cavendish Valery and Gros Michel

Parameters	*Results*	
	Cavendish Valery	*Gros Michel*
Ashes (%)	0.660±0.003	0.76±0.029
Soluble solids (°Brix)	21.80±0.216	21.53±0.478
Acidity (% malic acid)	0.307±0.014	0,305±0,003
pH	5.22±0.049	5.36 ± 0.047
Moisture content (%)	72.67±0.063	73.44±0.032
Ripeness index	71.01±0.052	70.59±0.013

Table 3 Chemical analysis in passion fruit

Parameters	*Results*
Ashes (%)	0.760±0.003
Soluble solids (°Brix)	13.26±0.097
Acidity (% citric acid)	0.57±0.017
pH	3.44±0.049
Moisture content (%)	83.58±0.035
Ripeness index	6.03±0.005

Table 4. Treatments resulted from the factorial design applied according to the variable used and their respective levels.

Banana type	*Stabilizer*	*Viscosity (cP)*	*°Brix*
Cavendish Valery	CMC	5553.7	65.3
Gros Michel	CMC	5557.1	65.0
Cavendish Valery	GX	5748.6	59.7
Gros Michel	GX	5754.2	63.7
Cavendish Valery	GX	4890.9	59.9
Gros Michel	GX	5650.9	62.9
Cavendish Valery	CMC	5418.8	64.9
Gros Michel	CMC	5467.9	65.3

Table 5. Analysis of variance for viscosity

Source	*Sum of squares*	*Degrees of freedom*	*Medium square*	*F-ratio*	*P-value*

A: Stabilizer type	277.30	1	277.30	0.00	0.96
B: Banana type	83661	1	83661.0	0.93	0.38
Residues	449801	5	89960.3		
TOTAL (corrected)	533740				

Table 6. Analysis of variance for °Brix.

Source	*Sum of squares*	*Degrees of freedom*	*Medium square*	*F-ratio*	*P-value*
A: Stabilizer type	6.30	1	6.30	4.91	0.078
B: Banana type	25.56	1	25.56	19.92	0.007
Residues	6.42	5	1.28		
TOTAL (corrected)	38.28				

Table 7 Multiple range tests for °Brix by stabilizer type (LSD)

Contrast	*Sig.*	*Difference*	*+/- Limits*
CMC – GX	*	3.575	2.05908

*Indicates a significant difference.

Table 8. Analysis of variance for score by code

Source	*Sum of squares*	*Degrees of freedom*	*Medium square*	*F-ratio*	*P-value*
Between groups	20.755	7	2.965	3.76	0.0008
Intra groups	151.6	192	0.789583		
TOTAL (corrected)	172.355				

Table 9. Multiple Range Tests for score per code

Contrast	*Sig.*	*Difference*	*+/- Limits*
1972 - 1972-2	-	-0.24	0.495723
1972 - 1980	-	-0.28	0.495723
1972 - 1980-2	-	-0.28	0.495723
1972 - 1997	*	0.64	0.495723
1972 - 1997-2	-	0.4	0.495723

1972 - 2003	-	-0.2	0.495723
1972 - 2003-2	-	-0.08	0.495723
1972-2 - 1980	-	-0.04	0.495723
1972-2 - 1980-2	-	-0.04	0.495723
1972-2 - 1997	*	0.88	0.495723
1972-2 - 1997-2	*	0.64	0.495723
1972-2 - 2003	-	0.04	0.495723
1972-2 - 2003-2	-	0.16	0.495723
1980 - 1980-2	-	0	0.495723
1980 - 1997	*	0.92	0.495723
1980 - 1997-2	*	0.68	0.495723
1980 - 2003	-	0.08	0.495723
1980 - 2003-2	-	0.2	0.495723
1980-2 - 1997	*	0.92	0.495723
1980-2 - 1997-2	*	0.68	0.495723
1980-2 - 2003	-	0.08	0.495723
1980-2 - 2003-2	-	0.2	0.495723
1997 - 1997-2	-	-0.24	0.495723
1997 - 2003	*	-0.84	0.495723
1997 - 2003-2	*	-0.72	0.495723
1997-2 - 2003	*	-0.6	0.495723
1997-2 - 2003-2	-	-0.48	0.495723
2003 - 2003-2	-	0.12	0.495723

*Indicates a significant difference.

Table 10. Physicochemical parameters evaluated in the syrups.

Parameters	*Results*
Ashes	2,18 ± 0,07
Soluble solids (°Brix)	64,30 ± 0.04
Acidity (% citric acid)	0,37 ± 0,09
pH	4,04 ± 0,02
Moisture	29,01 ± 0,16
Density	1,27 ± 0,02
Viscosity	5405.2 cp

Color	400-470 nm
Reducing sugars	23,7% (of which: fructose, 11.9%; glucose, 11.8%; lactose: < 0.1%; sucrose: 35.4%)

Discussion

Table 2 presents the ash content percentages for the Cavendish Valery and Gros Michel banana varieties. These percentages are comparable to those reported by López-Calvo et al. (2011) but differ from those reported by Martínez-Cardozo et al. (2016) reporting 2.5%. The percentage of soluble solids (22.2%) is similar to that presented by Arrieta et al. (2006). Other authors, such as Campuzano et al. (2010), reported lower values ranging from 16-20 °Brix, while Barrera et al. (2010) reported higher values of 26 °Brix compared to the findings of this study. The acidity, expressed in malic acid, was 0.307% for both varieties, and this value is comparable to that expressed by Campuzano et al. (2010) (0.25%). However, it differs from those reported by Barrera et al. (2010) (0.54%) and Ciro-Velásquez et al. (2005) of 0.60%. Table 2 presents the percentage of ash in Cavendish Valery and Gros Michel varieties, which are similar to those reported by López-Calvo et al. (2011) but differ from those reported by Martínez-Cardozo et al. (2016) of 2.5%. The percentage of soluble solids is comparable to that presented by Arrieta et al. (2006) of 22.2%, although other authors, such as Campuzano et al. (2010), report lower values (16-20 °Brix), while Barrera et al. (2010) report higher values (26 °Brix) than those found in this study. The acidity, expressed in malic acid, of 0.307% in both varieties is comparable to that expressed by Campuzano et al. (2010) of 0.25%, but differs from that reported by Barrera et al. (2010) (0.54) and Ciro-Velásquez et al. (2005) of 0.60%. The pH values of the two varieties are similar to those reported by Ciro-Velásquez et al. (2005) of 6%, Campuzano et al. (2010) of 5.20%, and Barrera et al. (2010) of 5.3%, while higher than those reported by Aurore et al. (2009) of 4.20%, Pimentel et al. (2010) of 4.13%, and Arrieta et al. (2006) of 4.6%. Moisture values in the banana pulp of the two varieties are higher than those reported by Lucas-A et al. (2013) (58.1%) and comparable to that described by Campuzano et al. (2010) (76%). These variations may be attributed to climatic conditions, soil composition, sample preparation, ripening stages, and physiological and biochemical processes subjected to fruit genetics. As the fruit ripens, the carbohydrate content increases due to the conversion of starch to sucrose and glucose which, in turn, raises the °Brix content and the amount of water, increasing its humidity, and lowers the acidity due to the respiration process (Torres et al., 2015). The color of the peel of the raw materials used in the study corresponds to a color index of 6-7 according to the Von Loesecke scale. The sugar/acid ratio used to calculate the ripening indexes of passion fruit juice were around 71. The ash content was approximately 0.76%, which is lower than the value reported by Martinez et al. (2017) of 1%. The percentage of soluble solids was similar to that presented by López et al. (2017) of 13.76%; other studies such as Aular & Rodriguez (2003), Cruz et al. (2010), and Martinez et al. (2017) reported higher values. The acidity, expressed in citric acid, was 0.57%, comparable to that reported by López et al. (2017), but differed from Aular & Rodriguez (2003) and Cruz et al. (2010). The pH value obtained was similar to that reported by López et al. (2017), but differed from Aular & Rodriguez (2003), Cruz et al. (2010), and Martínez et al. (2017). The moisture content in Passion fruit juice was 72.24%, similar to that reported by Martinez et al. (2017). These variations may be due to the physiological activity during ripening, as well as the altitude, ambient temperature, growing soils, and genetics of the plant species, as reported by previous studies.

Multiple range tests (Table 9) indicated that the formulation containing Gros Michel and Carboxymethylcellulose did not show statistically significant differences between its original and its replica at a 95.0% confidence level compared to the other samples. Additionally, this formulation obtained the highest means. The physicochemical parameters of the best syrup formulation containing banana Gros Michel and Carboxymethylcellulose were evaluated in this study, the percentage of ash fell within the range (0.03-2.7%) reported by Bonilla-Leiva & Gonzalez-Carbajal, (2000), exceeded the maximum limit of 1% established by Buenaño-Hernández (2017) and met the requirements of NMX-F-169, (1984) (0-3%). The percentage of soluble solids (°Brix) was within the range (58-64) reported by several authors, including Rivera-Rodríguez et al., (2005) and Luis et al. (2021), and coincided with the Peruvian standard RMNº 684-2005/MINSA (59). The acidity content of 0.27% was similar to the value reported by Rivera-Rodríguez et al., (2005) and lower than that reported by Rondón et al., (2019). The pH value complied with NMX-F-169, (1984) (min. 3) and was within the range reported by Bonilla-Leiva & Gonzalez-Carbajal, (2000) and Rivera-Rodríguez et al., (2005). The moisture content was similar to the value reported by Vargas-Díaz et al., (2019b) and within the range reported by Mellado-Mojica & López-Pérez, (2013), while it was lower than that reported by Espíndola Sotres et al., (2018) and Buenaño-Hernández, (2017). The color of the sample was a mixture of yellow and orange. The viscosity was measured in the Brookfield viscometer, and the values obtained were higher than those reported by Valenzuela, (2010) for sucrose syrup with coffee pulp. The reducing sugar content was fructose (46.9%), glucose (45.2%), and sucrose (6.1%), as reported by Bonilla-Leiva & Gonzalez-Carbajal, (2000), while Nieblas-Morfa et al., (2017) and Huiman-Arroyo and Luna-Jerí (2014) reported fructose (38.9%), glucose (6.2%), and sucrose (0.3%) for sisal syrup, and for agave, fructose (69.7%), glucose (28.08%), and sucrose (1.4%) were reported.

Conclusions

The Gros Michel species is an ideal raw material for banana syrup production due to its relevant contents of soluble solids and organic acids. Additionally, Passion fruit proved to be a suitable ingredient for use in the formulation. The statistical analysis of the chemical evaluation showed that the type of stabilizer used did not significantly impact viscosity, although it affected the soluble solids content. The physicochemical analysis of the formulation of banana syrup with Passion fruit juice (consisting in 40% water, 40% banana, 15.16% sugar, 4.24%, Passion fruit, 0.4% stabilizer, 0.1% preservatives, and 0.1% citric acid) resulted in 2.18% ash, 64.30% soluble solids, 0.37% acidity, a pH value of 4.04, 29.01% moisture, 1.27 $g.cm^{-3}$ density, 23.7% total reducing sugars, 5405.2 cp viscosity, and color ranging from yellow to orange (400-470 nm). The sensory evaluation described the product as highly sweet, viscous, and possessing a typical banana aroma. These findings suggest that the syrup obtained can be used as a substitute for conventional sugar in desserts, ice cream, and other applications with commercial potentials.

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