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LINEAR CORRELATIONS BETWEEN PHYSICOCHEMICAL PARAMETERS IN CASE OF SOME EXOTIC FRUIT COMPOTES

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Abstract. *The physicochemical properties of processed fruit products are important indicators of their quality, stability and nutritional value. Understanding the relationships between these properties can contribute to improved characterization and control of fruit-derived foods. The aim of this study was to investigate the statistical relationships between selected physicochemical parameters of exotic fruit compotes prepared from pineapple (Ananas comosus) and mango (Mangifera indica). Experimental samples were produced in three formulations: without additives, with brown sugar and with non-caloric sweetener. The analysed parameters included pH, total soluble solids (TSS), electrical conductivity (G) and dynamic viscosity (η). Physicochemical measurements were performed using standard analytical methods, while statistical analysis was carried out using linear regression models and analysis of variance (ANOVA) in STATISTICA 10 software. The results revealed statistically significant correlations between several physicochemical parameters. A strong negative correlation was observed between pH and electrical conductivity ($r = -0.81$, $p < 0.05$), indicating that increased ionic concentration is associated with decreased pH values. Additionally, a strong positive correlation was identified between refractive index and dynamic viscosity ($r = 0.86$, $p < 0.05$), suggesting that sugar concentration plays a major role in determining the rheological behaviour of fruit compotes. These findings demonstrate that physicochemical parameters can serve as reliable indicators for quality characterization of exotic fruit compotes.*

***Keywords**: exotic fruit compotes, physicochemical parameters, viscosity, electrical conductivity, regression analysis.*

INTRODUCTION

The consumption of fruit and fruit-based products has increased considerably due to their recognized nutritional and functional benefits. Fresh fruits are products of great importance in a rational diet, having numerous health benefits, due to their nutritional properties. Rich in carbohydrates, cellulose, minerals and antioxidant compounds, being sources of vitamins: A, B1, B5, C, enzymes and fiber, they should not be missing from a rational daily nutrition. Fruits can be consumed fresh or can also be prepared in various food products, such as juices, nectars, soft drinks or fermented fruit drinks, syrups, jams or fruit compotes (BANU et al., 2004; VICENTE et al., 2009).

Among tropical fruits, pineapple (*Ananas comosus* L.) and mango (*Mangifera indica* L.) are widely appreciated due to their nutritional value and sensory characteristics. Pineapple contains significant quantities of vitamin C, B-complex vitamins and minerals such as potassium and magnesium, while mango is rich in carotenoids, vitamin A and vitamin C. Pineapple is a perennial herbaceous plant of the *Bromeliaceae* family with the botanical name *Ananas sativus* or *Bromelia* pineapple. It originates in the tropical regions of America and the Far East. It is cultivated for its large fruit with a weight of 700 -2500 g. The pulp of this fruit is hard, sweet-sour taste (CHAUDHARY et al., 2019).

Pineapple is used in both fresh and juice or compote diet due to the high-water content (75-90%) and the intake of minerals and vitamins. Pineapple fruits are very rich in carbohydrates, predominantly sucrose, with a content of about 8.6%. 100g of pineapple contains calcium (13mg), potassium (115mg), magnesium (12mg), iodine (0.28mg), phosphorus (8mg) (DULL,1971). Pineapple also has a high quantity of vitamin B (B1, B2, B3, B5, B6, B9), C (36.2 mg per 100g) and is an important source of antioxidants (HOSSAIN et al., 2015). With its content, the pineapple helps digestion, maintains skin elasticity, combats bronchitis, increases immunity of the body, strengthens the bone system. The energy value of fruits is given by sugar, protein and fat content. For pineapple, the energy value is 48 Kcal per 100g of fruit, a relatively low value that recommends it to be used in diets (JOY, 2010; AMARAVATHI et al., 2014).

Mango is a fruit belonging to the *Mangifera genus*, which consists of numerous tropical fruit species belonging to the *Anacardiaceae* family. The tree comes from East Asia, Myanmar, Assumer. 100 grams of mango contain 0.82 grams of protein, 0.38 grams of fat, 14.98 grams of carbohydrates (of which 13.66 grams of sugar) and 1.6 grams of fiber, 36.4 mg of vitamin C, 54 micrograms of vitamin A and 43 micrograms of folic acid. Mango also contains vitamin B6, vitamin K, potassium, calcium and iron, as well as antioxidants such as zeaxanthin and beta-carotene. The energetic value is 60 calories per 100g of fruit (BOLOS, 2023). Large amounts of vitamin C and vitamin A contained in mango, plus 25 different types of carotenoids, maintain our healthy and strong immune system. Mango fruit contains malic acid, tartaric acid and a trace of citric acid that helps to adjust the alkaline reserve of the body. It is good for digestion. Mango helps maintain skin and eye health, regulate blood sugar and lower cholesterol. Being a good source of vitamin A, vitamin E and selenium, mango also offers a protection against heart disease. Potassium-rich content is good for decreasing blood pressure. Consuming ripe mango with bark, seems to be a cure for dysentery, constipation, hemorrhoids and indigestion (COZMA et al., 2017; LAMBERT, 2022).

Due to their nutritional value and health benefits, pineapple and mango are increasingly used in food, both raw and processed. Due to their high perishability, these fruits are frequently processed into various food products, such as juices, jams and compotes. Natural juices and compotes are obtained by conventional industrial manufacturing methods. Sterilized compotes are obtained by heat processing and preserving fruit pieces in sugar syrup, which allows for an extended shelf life while maintaining most of the nutritional properties (NIAC, 2010; RUTA, TARCEA, 2018).

Physicochemical parameters, such as pH, soluble solids content, electrical conductivity and viscosity, are important indicators of food quality. The relationships between these variables can provide useful information about the compositional and structural characteristics of processed fruit products. Therefore, the objective of this study was to evaluate the statistical relationships between specific physicochemical parameters in pineapple and mango compotes, prepared with different sweetening formulations.

MATERIAL AND METHODS

Raw materials and compote preparation

Fresh pineapple and mango fruits, purchased from a hypermarket, were used for the compote's preparation. Three experimental variants were made: compote without added sweetener (control), compote with brown sugar and compote with non-caloric sweetener. The fruits were washed, peeled, cut into pieces and thermally processed according to conventional compote preparation procedures.

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The objectives of our study were to evaluate the physicochemical characteristics: viscosity (η), electrical conductivity (G), pH and total soluble solids content (TSS) for mango and pineapple fruit compotes and examine the existence of linear correlations among selected physicochemical parameters.

Physicochemical measurements

The determination of the physicochemical parameters was performed according to the AOAC Official Methods of Analysis, 2000. pH represents a measure of the acidity or basicity of a solution. It was defined as the co-logarithm of the activity of dissolved hydrogen ions (H^+). The pH was measured using a pH meter OP-211/2 equipped with a combined electrode OP-0808P, according to AOAC official methods. To perform the measurements, it was necessary to calibrate the pH meter in the acidic range.

The total soluble solids (TSS) and the refractive index were measured using the refractometry method, with the Abbe refractometer corrected to the equivalent reading at 20°C (AOAC, 2000). The refractometer must be calibrated by verifying the refractive index of distilled water, which is 1.3330 at 20 °C. Electrical conductivity was measured using a conductometer OK-112. Conductometric methods are physicochemical analysis techniques based on measuring the electrical conductivity of electrolyte solutions. To perform measurements, the conductometer must be adjusted, and the conductance must be less than 60 μS. Dynamic viscosity was determined using the Ostwald-type viscometer using the standard formula (COZMA, 2016).

Statistical analysis

Experimental data were analyzed using STATISTICA 10 software. Linear regression analysis was applied to evaluate relationships between physicochemical parameters using the model: $y = ax + b$, where: *a* = slope of the regression line; *b* = intercept.

The statistical significance of regression coefficients was tested using analysis of variance (ANOVA), and correlation strength was assessed using Pearson correlation coefficients. The purpose of the statistical analysis was to identify correlations between the analyzed parameters, by modelling them as linear functional relationships (ŻYWICA, BANACH, 2015).

RESULTS AND DISCUSSIONS

Determining the physicochemical parameters of fruit compote, namely pH, total soluble solids (TSS) content, refractive index, dynamic viscosity and electrical conductivity, allows a complex assessment of the quality, composition and stability of the analyzed product.

The purpose of this paper is to test that there exist functional dependencies between some physicochemical characteristics (pH, total soluble solids, electric conductivity and dynamic viscosity) in the case of various types of exotic fruit compotes. In our statistical analysis, pH, total soluble solids, electric conductivity and dynamic viscosity were noted by pH, n, G and η.

Relationship between pH and electrical conductivity

The regression analysis performed between pH and electrical conductivity revealed statistically significant results. The univariate significance tests for the regression coefficients are presented in Table 1.

Table 1

Unvaried Tests of Significance for the regression coefficients of the pH based on the G

Effect	SS	Freedom degree	MS	F	p
Intercept	155.7404	1	155.7404	156.3053	0.000000
G	26.9981	1	26.9981	27.0960	0.000133
Error	13.9494	14	0.9964		

As shown in Table 1 above, a linear regression analysis of the pH based on the electric conductivity G, was performed. It was determined that the proportion of variance in the pH (26.9981) was statistically significant (F=27.0960, df =1) for p value under 0.05, where the F ratio provided the test of statistical significance.

pH provides information on the degree of acidity, influencing both the microbiological safety and the sensory characteristics of the product. The obtained data provide similar pH values; the lowest pH value was obtained for pineapple fruit compote with sweetener (3.77) and the highest value for mango with brown sugar (3.91). The lowest values of pH were obtained in case of the mango fruit compote without sugar (3.85) and the highest value of pH was for mango with brown sugar (3.94) (COZMA et al., 2015).

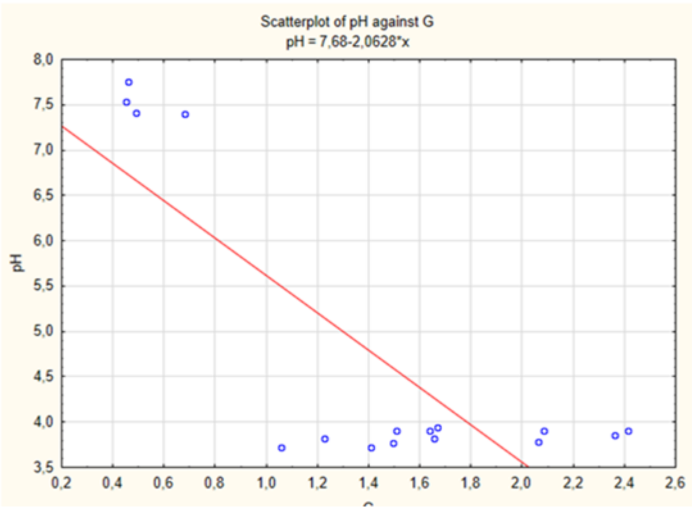

Figure 1. Regression line of pH as a function of electrical conductivity (G)

Electrical conductivity is influenced by dissolved ionic compounds, including organic acids and mineral salts, which explains the relationship between conductivity and pH. The regression line $y=b_0+b_1x$ is the linear equation used to fit the best straight line to the data (Figure 1). The dependent variable pH was expressed as the equation:

$$pH = 7.68 - 2.0628 \cdot G$$

The 95% confidence interval for the slope -2.0628 was (-2.91, -1.21) and the 95% confidence interval for the intercept 7.69 was (+6.36, +8.99), which provides the lower and upper bounds for the unstandardized regression coefficients. We noted that the 95% confidence interval does not include 0 suggesting that the slope is significantly different than 0 which

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means there is a strong linear relationship between pH and G. In fact, the strong negative linear correlation was reported by the Pearson linear correlation coefficient r = -0.81 and determination coefficient r^2=0.65.

Electrical conductivity indicates the presence of dissolved ions, providing information about mineral content and possible variations in chemical composition. There are no statistically significant differences between the electrical conductivity distributions for the samples analyzed. The lowest values of G were obtained for the mango compote with brown sugar (1.50 mS) and the highest value were obtained for mango compote with sweetner (2.41 mS). Electrical conductivity or specific conductance is a property of food material that measures their capacity to conduct the electric current. Electrical conductivity of food material is a function of product characteristics (composition, sugar and salt content, pH etc.). The electrical conductivity of the fruit compotes is affected by fruit maturity, growing areas and their climatic characteristic, storage conditions etc. (LAMSAL, JINDAL, 2014).

Relationship between dynamic viscosity and refractive index

Table 2

Unvaried Tests of Significance for the regression coefficients of the η based on the n

Effect	SS	Freedom degree	MS	F	p
Intercept	6.591687	1	6.591687	38.43627	0.000023
n	6.941991	1	6.941991	40.47890	0.000018
Error	2.400952	14	0.171497		

As shown in Table 2 above, we also performed a linear regression analysis of the refractive index, n based on viscosity η. It was determined that the proportion of variance in the dynamic viscosity (6.94) was statistically significant (F=40.4789, df =1) for p value under 0.05, where the F ratio provided the test of statistical significance. The results show that the variation in viscosity explained by refractive index is statistically significant (F = 40.48, $p < 0.05$). The relationship between these variables is illustrated in Figure 2.

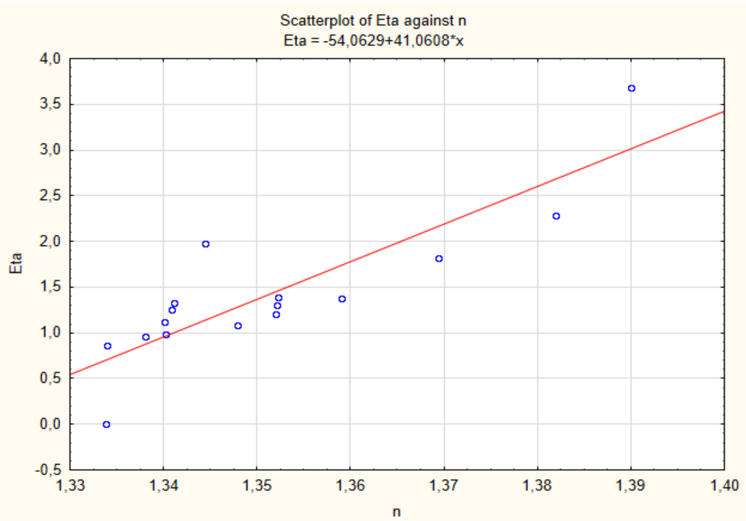

Figure 2. Regression line of dynamic viscosity (η) as a function of refractive index (n)

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The regression line $y=b_0+b_1x$ is the linear equation used to fit the best straight line to the data (Figure 2). The dependent variable η was expressed as the equation:

$$\eta = -54.0629+41.0608\cdot n$$

The 95% confidence interval for the slope +41,0608 was (+27.21, +54.90) and the 95% confidence interval for the intercept -54.0629 was (-72.76, -35.35) which provides the lower and upper bounds for the unstandardized regression coefficients. We noted that the 95% confidence interval does not include 0 suggesting that the slope is significantly different than 0 which means there is a strong linear relationship between η and n. In fact, the strong positive linear correlation was reported by the Pearson linear correlation coefficient r= -0.86 and determination coefficient r^2= 0.74.

There are some statistical insignificant differences between simple pineapple and mango fruit compotes with brown sugar, but there are significant differences in case of pineapple and mango fruit compotes without addition and with sweetener and brown sugar. The sweetener doesn't change the refractive index and the viscosity too much. Fruit compotes have a high refractive index due to their elevated sugar concentration.

TSS expresses the content of soluble substances, especially sugars, being an indicator of the sweetness and concentration of the compote. The refractive index is directly correlated with the content of soluble solids and is frequently used for their rapid determination, also allowing verification of uniformity and possible deviations from the standard composition. The refractive index of a carbohydrate solution increases proportional with sugar concentration. High concentration of sugar in fruit samples gives high value of refractive index (KUMAR, KIRAD, 2013).

The sugar concentration modifies the viscosity too. Dynamic viscosity reflects the consistency and texture of the product, influencing its sensory perception and technological behavior. This can explain the strong positive linear correlation between the viscosity and the index of refraction (MOMIN, THAKRE, 2015; COZMA et al., 2017).

The correlation coefficient (r = 0.86) indicates a strong positive relationship between viscosity and refractive index. The coefficient of determination (r^2 = 0.74) suggests that approximately 74% of viscosity variation is explained by changes in refractive index.

This relationship can be attributed to the influence of soluble solids concentration, particularly sugars, which increase both refractive index and solution viscosity.

CONCLUSIONS

The determination of the physicochemical parameters for the analyzed fruit compotes, namely pH, total soluble solids (TSS), refractive index, dynamic viscosity and electrical conductivity, allows a complex assessment of the quality, composition and stability of the product.

The results of this study demonstrate the existence of significant relationships between several physicochemical parameters of pineapple and mango compotes.

A strong negative correlation was observed between pH and electrical conductivity, indicating the influence of ionic composition on acidity. In addition, a strong positive correlation was identified between refractive index and dynamic viscosity, reflecting the role of soluble solids concentration in determining rheological properties. The results correspond to those described in the literature.

The results highlight the importance of physicochemical parameters as useful indicators for characterizing the quality of fruit compotes. Also, the use of alternative sweeteners did not significantly modify the fundamental relationships between the analyzed variables. Overall, these parameters provide an integrated picture of the quality of the compote, being essential for controlling the technological process and ensuring the conformity of the finished product.

Future research should include larger data sets and a greater diversity of fruit types, to better understand the complex physicochemical interactions that occur in processed fruit products.

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