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Development of pineapple jam incorporated with chia seed and honey

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Abstract: This study aims to explore the different characteristics of incorporating chia seed and honey instead of conventional pectin and sugar in pineapple jam preparation. Three different combinations of chia seed and honey were implemented to develop pineapple jam formulations, and then the characteristics were analyzed. The results showed noteworthy changes in the composition, texture, physicochemical, and color characteristics of the jam based on chia seed and honey content, but consumers preferred the commercial jam. Overall, this investigation brings attention to the potential advantages of applying chia seed powder and honey to pineapple jam, providing insights into its nutritional and sensory implications.

Keywords: Chia seed; Honey; Pineapple jam; Proximate composition; Sensory analysis; Texture analysis.

1. Introduction

Fruits are a common natural source of various nutritional components, and they play a significant role in a country's economy. However, human choices, market demand, availability, and weather conditions are changing dramatically at present. Also, fruits are highly perishable, and their cultivation depends on the season. So, it is important to process these fruit products into more stable forms. In this perspective, the preparation of jams, jellies, and juices is one of the best choices to preserve the bioactive and nutritional components and get benefits throughout the whole year (Shinwari & Rao, 2018).

Fruit jam is one type of semi-solid processed food item, which is prepared from the extracted meat or juice of fruits, heated with sugar, water, pectin, acid, and other ingredients. Different nutritional components, such as fibers, proteins, vitamins, and antioxidant components, exist in fruit jam (Dubey et al., 2021). According to EU Council guidelines in 2004, jam is the combination of puree of one or more fruits, or pulp, sugar, which forms a gel structure with the appropriate consistency (Abid et al., 2018). Pineapple is a wonderful tropical fruit that has exceptional juiciness, vibrant tropical flavor, and immense health benefits. Pineapple (Ananas cosmosus), a member of the Bromeliaceae family, is high in nutrient content with an excellent flavor (Hossain & Islam, 2017). In 100 g of pineapple fruit, it exists 12 g of carbohydrate, 0.2 g of fat, 1.2 g of protein, and 1.4 g of fiber. Pineapple is one of the most familiar fruits in Bangladesh, following banana and orange. Although the weather conditions in Bangladesh are good for growing pineapple, every year a significant proportion are lost during and after the harvesting time, which causes high economic losses. Insufficient marketing information, far distance and narrow mobility, impoverished infrastructure, and poor storage facilities inhibit the losses of pineapple crops in the harvesting season (Hasan et al., 2024). To reduce the postharvest losses and economic losses, pineapple fruits can be processed into shelf-stable products such as pineapple jam. Preparation of pineapple jam is a beneficial food preservation strategy because of its availability in the off-season, low cost, and organoleptic properties (Muresan et al., 2014).

However, there are some disadvantages when pineapple pulp is cooked into pineapple jam. There is a lower amount of vitamin C content in jams than in the natural fruit because of heat application during jam processing (Mohd Naeem et al., 2017). Moreover, other nutritional components and mineral components are reduced and converted into trace fat and sugar (Nduko et al., 2018).

To mediate these problems, the addition of chia seed powder can help replenish of nutrient loss during processing. Chia seeds (Salvia hispanica) are small, black, or white seeds that are a good source of dietary fiber, plant protein, vitamins, and minerals, which make them a popular ingredient in functional foods. Vitamin B1, vitamin B2, niacin, phosphorus, calcium, potassium, and magnesium are kinds of vitamins and minerals, which are available in chia seeds (Jin et al., 2012). Chia seeds are also rich in different polyphenols and phytocompounds (Motyka et al., 2023; Oliveira-Alves et al., 2017). Another striking features of chia seed are hydrophilic properties, high viscosity, water-holding capacity, oil-holding capacity, emulsifying and stabilizing properties, which can influence the rheological behavior of food products (López et al., 2019; Timilsena et al., 2015). So, chia seed can be utilized as a thickening, gelling, and coating agent in the developed jam products (López et al., 2019; Timilsena et al., 2015). Traditionally,

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sugar and pectin are common ingredients that are employed to prepare jam. Pectin is a pectic polysaccharide component that acts as a gelling agent during the jam processing. Sugar is added to jam preparation for different purposes, such as to act as a preservative, set the pectin, and make the product glisten. Low level of sugar content makes the jam tough, whereas excessive level of sugar makes the fruit jam soft, which can be easily broken. But a higher level of sugar is not beneficial for human health, whereas honey is healthier than sugar. Honey is a natural sweetener that has been used in food production for centuries. It is rich in antioxidants, vitamins, and minerals, making it a wholesome food alternative to refined sugars. Therefore, the addition of chia seeds and honey in pineapple jam is a promising strategy to substitute for sugar and pectin.

Previously, Nduko et al. (2018) demonstrated the fortification of pineapple jam with chia seed, where they used sugar and pectin. Grigelmo-Miguel & Martín-Belloso (1999) also developed strawberry jam, which was formulated with peach dietary fiber. (Saleem et al., 2024) also developed pumpkin and strawberry jams by the addition of chia seeds. Therefore, jams can be formulated with soluble dietary fibers. Different soluble dietary foods might be used as functional components of the developed jam. However, very few references are available where chia seed is used as a gelling agent and dietary food component. In addition, no work is found about the preparation of pineapple jam, fortified with chia seed and honey combined instead of pectin and sugar.

Therefore, the objective of this research work was to formulate an acceptable pineapple jam together with chia seeds and honey. Another objective of this work was to evaluate the proximate analysis, physicochemical characteristics, texture analysis, and sensory evaluation of the developed jams.

2. Methods

2.1 Materials

Only fresh, mature, and sound pineapple fruits were purchased from the local K.R. market in Bangladesh. Chia seed and honey used in this study were collected from the same market. The materials were then transported to the Department of Food Technology and Rural Industries laboratory. Other relevant reagents and apparatus required for the experiments, such as citric acid, distilled water, conical flask, pipette, burette, refractometer, etc., were provided by the laboratory of the Department of Food Technology and Rural Industries. The chemicals and solvents used in the study were of analytical reagent grade and were used from the laboratory stock.

2.2 Experimental Procedures

2.2.1 Pulp extraction

Fresh pineapple fruits were sorted according to uniform color and ripeness. Sorted fruits were washed with present tap water to clean the dirt and other foreign materials. Then, the stainless-steel knife was used to cut the fruits into pieces. The inedible portions were removed using a clean table knife, and the edible pulp was blended separately using a blender and kept in a refrigerator until used. The minimum and maximum temperatures during the study period of the storage room was 5° to 9°C, respectively, for further physicochemical characterization. **Fig. 1** described the flow diagram showing the process of pineapple jam using chia seed and honey.

2.2.2 Preparation of pineapple jam with chia seed and honey

Chia seed was ground to make chia seed powder, and that powder was used as a gelling agent in pineapple jam. Pineapple jam was prepared based on the formula and procedure given by (Jori et al., 2013). The pineapple pulp was mixed with chia seed powder and honey. The mixture was heated to maintain 90°C for the best products in terms of their nutritional composition, color, phytochemicals, and vitamin C. Citric acid for pH was adjusted to 3. The mixture was stirred continuously and heated until the final product contained 67% of soluble solids measured by refractometer (Bellingham & Stanley Ltd., Tunbridge Wells, United Kingdom) at 20°C. Hot jams were poured into glass jars with screw caps and stored at 4°C until use. Three pineapple jam formulations (S1, S2, S3) were prepared with different amounts of chia seed powder. Pineapple pulp, honey, and citric acid amounts were constant for all formulations. The conditions of prepared jam formulations are represented in **Table 1.**

2.2.3 Proximate analysis

According to the method of AOAC (2019), proximate analysis of the four pineapple jam samples was performed through moisture content, ash content, fat content, protein content, and crude fiber content determination.

2.2.4 Sensory analysis

Sensory evaluation was conducted at the Department of Food Technology and Rural Industries laboratory, Bangladesh Agricultural University. 10 panelists were selected from the teachers, students, and employers of the Department of Food Technology and Rural Industries. Before starting the analysis, panelist members were instructed orally about the directions of the analysis and attributes including color, flavor, texture, and overall acceptability. Each panelist was provided with paper cups to serve the jams as well as a scorecard. The hedonic rating test was used to determine this acceptability. For statistical analysis of sensory data, 9-point hedonic rating test was used to assess the degree of acceptability. Jams were served to the panelists, and they were asked to assign appropriate scores for characteristics of color, flavor, texture, and overall acceptability of jams. The rating scale was like extremely (9), like very much (8), like moderately(7), like slightly (6), neither like nor dislike (5), dislike slightly (4), dislike moderately (3), dislike very much (2), dislike extremely (1).

2.2.5 Texture analysis

The textural parameters of pineapple jam samples, including hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness, were determined by the TPA (Texture profile analysis) test. A Texture Analyzer (Analysis LLOYD instruments, Fareham, UK) interfaced with a laboratory computer (Windows-based Software NEXYGEN PLOT) was used to measure the force-time curve for a two-cycle compression. Jams were poured into plastic food containers with a height of 40 mm. A cylindrical probe (19 mm diameter) was used to compress the sample to a 20 mm depth with a displacement speed of 40 mm/min. All instrumental texture analyses were conducted at room temperature. The texture data were recorded as force versus time.

2.2.6 Physicochemical properties analysis

2.2.6.1 Titratable acidity determination

Titratable acidity was determined using the AOAC (2019) method. 5 g of the sample was blended, homogenized, and then filtered. 10 ml of filtered liquid was titrated using phenolphthalein indicator against 0.1 N NaOH. The titratable acidity was calculated by the following:

$$\% \text{ of titratable acidity} = \frac{T \times N \times V1 \times E}{W \times V2 \times 1000} \times 100$$

Where, T=Titre, N=Normality of NaOH, V1 = Volume made up, E= Equivalent weight of acid, W= Weight of sample, V2= Volume of sample taken for estimation.

2.2.6.2 Vitamin C determination

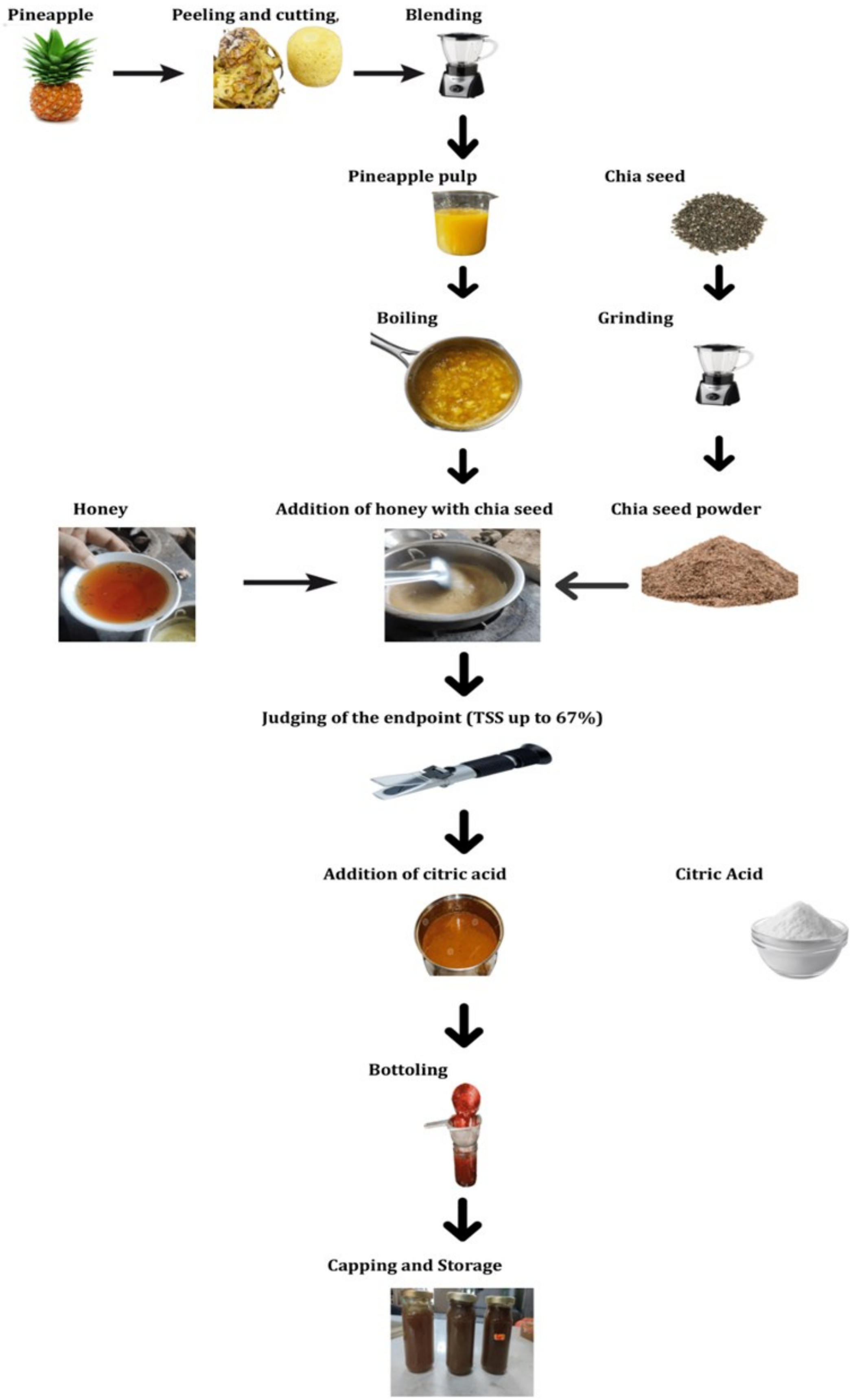

Fig.1. Schematic of pineapple jam process with chia seed and honey

Table 1. The amount of pineapple pulp, honey, and chia seed in three different pineapple jam formulations.

Sample	Pineapple pulp (g)	Honey (g)	Chia seed (g)
S1	250g	100g	5g
S2	250g	100g	7.5g
S3	250g	100g	10g

[*C = Control (only pineapple jam), which buys from the local market. S1 = Sample 1 (40% honey and 2% chia seed), S2 = Sample 2 (40% honey and 3% chia seed), and S3 = Sample 3 (40% honey, and 4% chia seed). g indicates gram, which is the unit of mass in the centimetre-gram-second system.]

Table 2. Determination of moisture, ash, fat, protein, and fiber of control (only pineapple jam) sample and developed pineapple jam formulations with chia seed and honey

Sample	Moisture (g/100g)	Ash (g/100g)	Fat (g/100g)	Protein (g/100g)	Fiber (g/100g)
Control	29.97 ± 0.45^{b}	0.06 ± 0.002^{a}	Nil	2.45 ± 0.015^{a}	0.14 ± 0.002^{a}
S1	29.50 ± 0.44^{b}	1.47 ± 0.014^{b}	0.35 ± 0.015^{b}	3.70 ± 0.025^{b}	0.56 ± 0.015^{b}
S2	29.06 ± 0.09^{b}	2.02 ± 0.004^{c}	0.50 ± 0.02^{c}	4.97 ± 0.011^{c}	1.48 ± 0.015^{c}
S3	24.95 ± 1.35^{a}	2.35 ± 0.010^{d}	0.71 ± 0.01^{d}	6.58 ± 0.011^{d}	1.65 ± 0.015^{d}

[Values are expressed as means of three replicates ± standard deviation. Mean values followed by different subscripts within columns are significantly different by Duncan's multiple range tests ($p < 0.05$), and similar superscript are not significantly different ($p > 0.05$). g indicates gram, which is the unit of mass in the centimetre-gram-second system]

Table 3. Sensory attributes evaluation of control (only pineapple jam) sample and developed pineapple jam formulations with chia seed and honey.

Sample	Color	Texture	Flavor	Overall acceptability
Control	7.46 ± 0.152^{c}	7.76 ± 0.987^{b}	7.52 ± 0.170^{b}	7.24 ± 0.052^{d}
S1	6.66 ± 0.115^{a}	6.75 ± 1.23^{a}	6.77 ± 0.293^{a}	6.60 ± 0.10^{a}
S2	7.06 ± 0.208^{b}	7.18 ± 0.436^{ab}	6.99 ± 0.130^{a}	7.10 ± 0.040^{c}
S3	6.86 ± 0.152^{ab}	6.75 ± 1.034^{a}	6.73 ± 0.149^{a}	6.79 ± 0.060^{b}

[Values are means of three replicates ± standard deviation. Mean values followed by different subscripts within columns are significantly different by Duncan's multiple range tests ($p < 0.05$), and similar superscript are not significantly different ($p > 0.05$).]

Table 4. Texture parameters evaluation of control (pineapple jam) sample and three developed pineapple jam samples formulated with chia seed and honey.

Sample	Hardness (dyne)	Adhesiveness (dyne. sec)	Cohesiveness	Springiness (%)	Gumminess (dyne)	Chewiness (dyne)
Control	2.24×10^{4}	20.87×10^{3}	0.48	46	10.75×10^{3}	4.94×10^{3}
S1	3.73×10^{4}	14.61×10^{3}	0.402	30.33	14.99×10^{3}	4.50×10^{3}
S2	14.93×10^{4}	10.35×10^{3}	0.284	26.52	42.40×10^{3}	11.23×10^{3}
S3	8.95×10^{4}	11.62×10^{3}	0.400	35	35.42×10^{3}	12.40×10^{3}

[Values indicate the different parameters of texture evaluation for one replicate. Dyne is the unit of force in the centimeter-gram-second system. Dyne-second (dyne.sec) is the unit of adhesiveness in the centimeter-gram-second system.]

Standard ascorbic acid solution and dye solution were prepared. Titration was performed, and the dye factor was determined using the following formula:

$$\text{Dye factor} = \frac{0.5}{Weight\ of\ the\ sampTitree}$$

5 g of sample was made up to 100 ml volume with 3 % HPO3, and then filtered. Then, the aliquot was mixed with 1 ml of formaldehyde (40%), and 0.1 ml of HCl. This mixture was titrated with standard dye, and the volume (V1) was estimated. The gm of vitamin C per 100 gm sample was calculated using the following formula:

$$\text{Gram of vitamin C per 100 g sample} = \frac{T \times D \times V1}{V2 \times W} \times 100$$

Where, T = Titre, D = Dye factor, V1= Volume made-up, V2= Aliquot of extract taken for estimation, W = Weight of sample taken for estimation.

2.2.6.3 Viscosity determination

Viscosity measurement was carried out using the rotational viscometer (model NDJ-5S). The experiments were carried out at a specific 60 rpm with spindle 4 to measure the viscosity of jams having different compositions at 25 ± 1˚C.

2.2.6.4 Total soluble solid (TSS) determination

The total soluble solid (TSS) of the fruit pulp and jam was determined by an Abbe Refractometer (Model no. 8987, Pujikuki Ltd., Tokyo, Japan)

2.2.6.5 Total sugar determination

Sugar content was estimated by determining the volume of unknown sugar solution of the jam sample through complete reduction of standard Fehling's solution. The following procedures were followed in determining sugar content according to (Ranganna, S. 1997). Initially, 10ml of both Fehling's solution A and Fehling's solution B were mixed. The mixed solution was titrated with a standard sugar solution. Fehling's factor was calculated by the following formula:

$$\text{Fehling's factor} = \frac{Titre \times 2.5}{1000}$$

10 g of filtered juice and 100 ml of distilled water were mixed in a homogenizer and neutralized with 0.1 N NaOH; then 2 ml of lead acetate solution was added. After 10 minutes, 5 ml of potassium oxalate solution was added to make 250 ml. Finally, it was filtered and diluted.

10 ml of mixed Fehling's solution was taken in a conical flask, and 25 ml of distilled water was added to it. Purified juice was taken in a burette. The conical flask containing mixed Fehling's solution was added to the flask when boiling started and titrated with solution taken in the burette at the same time. The endpoint was indicated by the decolorization of the indicator. Percent reducing sugar was calculated by using the following formula:

$$\text{\% of reducing sugar} = \frac{I \times D \times 100}{T \times W \times 1000}$$

Where,

I = mg of inverted sugar required to reduce the known volume of Fehling's solution, D = Dilution factor, T = Titre, W = Weight of the sample.

50 ml of purified solution was mixed with 50 ml of distilled water and 5 g of citric acid. This mixture was heated for 10 minutes to dissolve the sucrose, and finally it was cooled. The sample was then neutralized by 0.1 N NaOH solution using a phenolphthalein indicator. The mixed Fehling's solution was titrated using a procedure similar to that followed in the case of reducing sugar, and the percentage of inverted sugar was calculated.

% of non-reducing sugar = % of invert sugar - % of reducing sugar

2.7 Color determination

The color of the pineapple jam was measured using a Colorimeter (Flexitext-NR110). CIE-L*a*b* color coordinates (10˚ observer and D65 illuminant) were obtained using the colorimeter.

2.8 Statistical Analysis

The collected data on various parameters is statistically analyzed using SPSS statistical software. One-way analysis of variance (ANOVA) is carried out, and mean separation is done with Duncan's Multiple Range Test (DMRT) with a significant ($p<0.05$) difference among all the samples.

3. Results

3.1 Proximate composition analysis

Table 2 presents the results of the proximate composition of the pineapple jam samples. Significant differences ($p < 0.05$) were found among the four experimental samples for ash, fat, protein, and fiber content; however, the statistical analysis of the three samples, including control, S1, and S2, was similar ($p > 0.05$) for moisture content. The statistical analysis illustrates that with the addition of chia seed, ash content, fat content, protein content, and fiber content increased, while the moisture content decreased.

The ash content, fat content, protein content, and fiber content of the commercial control and three produced jam samples ranged between (0.06 ± 0.002 g/100g to 2.35 ± 0.010 g/100g), (0 to 0.71 ± 0.01 g/100g), (2.45 ± 0.015 g/100g to 6.58 ± 0.011 g/100g), and (0.14 ± 0.002 g/100g to 1.65 ± 0.015 g/100g) respectively. It is also shown that sample S3 has the lowest moisture content value, 24.95 ± 1.35 g/100g when compared to the highest moisture content value in the commercial control, 29.97 ± 0.45 g/100g.

3.2 Sensory analysis

Sensory analysis is the evaluation of some characteristics, including color, texture, flavor, etc., and these parameters combinedly help to judge the overall acceptance scores. The parameters of the four pineapple jam samples are described in **Table 3**. The addition of chia seed and honey minimally reduced the sensory scores of jam samples regarding color, texture, flavor, and overall acceptance from (7.46 ± 0.152), (7.76 ± 0.987), (7.52 ± 0.170), and (7.24 ± 0.052), respectively to (6.66 ± 0.115), (6.75 ± 1.034), (6.73 ± 0.149), and (6.60 ± 0.10), respectively. Commercial jam sample and the other three formulated jam samples were significantly different ($p > 0.05$) for the four sensory attributes.

3.3 Texture analysis

Table 4 reveals the texture analysis of the four samples, including hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness. For hardness and gumminess attributes, the values of the pineapple jam samples increased with the addition of chia seed and honey. The commercial control sample had the lowest values, 2.24×104 dyne and 10.75×103 dyne, respectively, for hardness and gumminess, whereas the highest values were 14.93×104 and 42.40×103, respectively, in sample S2.

On the other hand, the values of adhesiveness, cohesiveness, and springiness reduced in three samples, S1, S2, and S3, after addition of chia seeds. Lowest scores for adhesiveness (10.35×), cohesiveness (0.284), and springiness (26.52) were observed in sample S2, whereas commercial control sample showed the highest scores, 20.87×, 0.48, and 46, respectively, for the attributes. In terms of chewiness, sample S1 and sample S3 had the lowest and highest scores, 4.50×103 and 12.40×103, respectively.

3.4 Physicochemical properties analysis

Different physicochemical properties were also investigated, including total titratable acid, vitamin C, viscosity, reducing sugars, and total sugars, and **Table 5** presents these parameters. Significant differences ($p < 0.05$) were observed among the four jam samples for both vitamin C and viscosity values, with sample S3 having the highest scores, 0.01341 ± 0.000205 g/100g for vitamin C and 58.33 ± 0.80 P for viscosity. On the other hand, commercial control sample had the lowest values, 0.00975 ± 0.000212 g/100g and 10.35 ± 0.77 P, respectively, regarding vitamin C and viscosity values.

In addition, the inclusion of chia seed and honey moderately changed the reducing sugar content and total sugar content, and the values of the parameters ranged from 18.11 ± 0.020 g/100g to 22.19 ± 0.251 g/100g, and 60.36 ± 0.321 g/100g to 65.01 ± 0.275 g/100g, respectively. No significant difference ($p > 0.05$) was noticed between samples S1 and S3 for both reducing sugar and total sugar content, but it existed ($p < 0.05$) between the other two samples.

There was a significant difference ($p < 0.05$) in the total titratable acid content between commercial control, S3 and sample S1, S2. Considering the control sample that had the highest total titratable acid concentration, 0.75 ± 0.035 g/100g, while sample S1 showed the lowest concentration 0.51 ± 0.016 g/100g.

3.5 Color analysis

The results of the color profile analysis of the four samples are showed by the **Table 6.** There was fluctuation of the values of L*, a*, and b* among the four samples. L* indicates the lightness, a* for greenish or reddish, and b* for yellowness. The lightness value (L*) of the control sample was 33.30 and after addition of chia seed and honey, the values modified in three samples (S1, S2, and S3) 36.40, 16.35, and 21.41, respectively. The a* value for the control sample was -3.09, and for the three different samples (S1, S2, and S3) were -1.68, -3.41, and 2.06, respectively. The negative value suggests a greener color, and the positive value for more red color. The b* value indicates the yellowness. The b* value for the control sample was 14.57, whereas 19.75, 14.90, and 7.26 for the three samples (S1, S2, and S3), respectively. Positive value indicates the more yellow characteristics of the samples.

4. Discussions

The quality of food products depends on the product's shelf life, which is calculated by the amount of moisture content (Lee & Robertson, 2022). Low moisture content shows the long shelf life of jam samples, whereas high moisture content means a short life span, which is prone to microbial attack by fungi and mold. In our study, the increased concentration of chia seed lowered the moisture content of the developed pineapple jam in the three samples S1, S2, and S3, respectively. A similar observation was detected in pumpkin and strawberry jam products after the addition of chia seed (Saleem et al., 2024). From Table 2, it was

Table 5. Physicochemical composition of control (pineapple jam) sample and three pineapple jam samples added with chia seed and honey.

Sample	Total titratable acid (g/100 g)	Vitamin C (g/100g)	Viscosity (P)	Reducing Sugars (g/100g)	Total sugars (g/100g)
Control	0.75 ± 0.035^b	0.00975± 0.000212^a	10.35 ± 0.77^d	18.11± 0.020^a	65.01± 0.275^c
S1	0.51 ± 0.016^a	0.01214 ±0.000067^b	40.35 ± 0.77^a	22.08± 0.137^c	62.76± 0.550^b
S2	0.56 ± 0.021^a	0.0128±0.00006^c	52.50 ± 0.84^b	20.35± 0.020^b	60.36± 0.321^a
S3	0.64 ± 0.113^b	0.01341±0.000205^d	58.33 ± 0.80^c	22.19± 0.251^c	63.30± 0.754^b

[Values are means of three replicates ± standard deviation. Mean values followed by different subscripts within columns are significantly different by Duncan's multiple range tests ($p < 0.05$), and similar superscript are not significantly different ($p > 0.05$). g indicates gram, which is the unit of mass in the centimetre-gram-second system]

Table 6. Color profile (L* a* b*) analysis of commercial pineapple jam and three pineapple jam formulations produced by chia seed and honey.

Sample	L*	a*	b*
Control	33.30	-3.09	14.57
S1	36.40	-1.68	19.75
S2	16.35	-3.41	14.90
S3	21.41	2.06	7.26

[Values indicate the color profile analysis of one replicate. L* = Lightness, a* = Green or Red coordinate, and b* = Yellow or Blue coordinate. Higher L* value of jam shows the darker color than other samples, positive value of a* indicates red and negative value of a* is for greener color, and higher b* value implies for more yellow characteristics.]

evident that chia seed combined with the pineapple jam increased the ash, fat, protein, and fiber composition of the pineapple jam products.

Ash content is the inorganic residue, and total mineral content in the food, which is achieved after burning of the organic material. The higher level of ash contents in the jam samples indicates the more mineral contents in the formulated samples than the commercial control. It is due to the presence of chia seed in the samples. There is around 31% fat in the chia seed, where α-linolenic acid exists around 64% and linoleic acid is around 19%. So, the presence of essential fatty acids increases the fat content level in the formulated jam samples, which implies the health beneficial effects, including coronary heart disease.

Among different cereals, chia seeds contain a higher amount of protein content, which ranges around 18-24% of their mass (Agarwal et al., 2023; Grancieri et al., 2019). Different exogenous amino acids, such as arginine, leucine, phenylalanine, valine, and endogenous amino acids, such as glutamic acid, aspartic acid, alanine, serine, and glycine, are present in chia seeds (Kulczyński et al., 2019). Therefore, the higher the amount of chia seed in the jam samples, the greater the protein level in the jam samples. Similarly, addition of chia seed also increased the fiber content level. Approximately 18-30 g dietary fiber is contained per 100 g (Cotabarren et al., 2019; Silveira Coelho et al., 2019).

Color, texture, flavor, and acceptability analysis combinedly result in the sensory analysis in **Table 3**. Higher preferences for color, texture, and flavor attributes were observed for the commercial control sample than for other formulated samples. In addition, for overall acceptability, the commercial control sample got a higher score. But it is noticeable that the gap between the scores of the samples was not significant. Therefore, it indicated that the addition of chia seed did not affect the sensory attributes of the jams. It means that consumers might not be well-adjusted when new ingredients are added to jam products.

According to **Table 4**, the hardness of the formulated jam samples increased dramatically, but cohesiveness and adhesiveness decreased dramatically. Strength of gel structure is implied by the hardness value, and with this value food products can maintain their structure against external force (Garrido et al., 2015; Mousavi et al., 2019). Cohesiveness defines the ratio of the area of positive force during the second compression to the first compression, whereas adhesiveness signifies a negative force area for the first bite (Chandra & Shamasundar, 2015; Garrido et al., 2015). So, lower adhesiveness and cohesiveness values imply the firmer gel formation in fruit jam products. Regarding this perspective, addition of chia seed and honey increased the strength of internal bonds of the pineapple jam products. Chewiness value is the product of hardness, cohesiveness, and springiness. Chewiness value indicates the energy value, which is required for swallowing after chewing jam products (Azari-Anpar et al., 2017). Since chia seed and honey increased the strength of the pineapple jam, chewiness value also increased (Culetu et al., 2014). This is consistent with the fact that the presence of honey and chia seed would increase the gumminess of the pineapple jam compared with the control samples.

Total titratable acidity is an essential characteristic to determine gel formation and restrict the growth of hazardous microorganisms. Among the three produced jam samples, S1, S2, and S3, titratable acidity increased slightly with the higher level of chia seed concentrations. This might be due to the presence of total soluble solid contents of the samples. In addition, vitamin C (ascorbic acid) is a water-soluble antioxidant, which shows scavenging activity of free radicals, such as reactive oxygen species (ROS). Similarly, vitamin C content increased slowly among the three produced jam samples with the increased level of chia seed in the pineapple jam. It indicates that chia seed can increase the vitamin C level in pineapple jam. Viscosity is another important parameter to evaluate the jam's resistance to movement. From **Table 5**, it is noticed that viscosity level increased fourfold with the inclusion of chia seeds in the formulated samples. High viscosity value attributes the high fiber content in the jam formulations (Nour et al., 2010).

Total sugar content of formulated jam products indicates the sweetness of the product. Total sugar content and reducing sugar content were observed in a reciprocal relationship in **Table 5**. Total sugar amount was decreased after addition of chia seed and honey,which suggests that honey had a minimal effect on total sugar level. However, there was an increase in reducing sugar content in the three samples S1, S2, and S3 compared to the control sample. Jams enriched with chia seed powder and honey had slightly higher reducing sugar content compared to the control, indicating a minor effect of honey on reducing sugar content. High amounts of reducing sugar may be helpful to reduce the risk of obesity, overweight, and dental caries.

The L* value is the lightness indicator, where a higher L* value suggests the jam had a darker color. Commercial control and sample S1 appeared darker than the other two formulations, S2 and S3, because of having a lower concentration of chia seed. The positive chromaticity indicator a* suggests the presence of red hue in the jams, and the negative a* value for the greener color. Highest concentration of chia seed in pineapple jam formulation S3 shows the strongest red hue among all samples. The positive parameter b* presents the yellowness in the jam products. **Table 5** suggests that yellowness decreased in the prepared jam formulations S1, S2, and S3 with the addition of chia seed. Since phenolic compounds degrade, color is changed, and causes browning in the jam formulations (Food Eng., 2006). Chemical reaction between reducing sugars and amino acids in open air also causes the browning in the prepared jam products (Ngo et al., 2007).

5. Conclusion

The pineapple jam samples prepared with chia seed and honey is very beneficial to health and had a relatively higher level of nutritional elements. However, commercial jam sample was preferable to consumers because of less sensory characteristics, undesirable appearance of the developed three jam samples. Among the three formulated jam samples, sample S2 (added with 3% chia seed) is more acceptable than other two. It suggests that formulation is as salient attribute as sensory and functional properties for the development of functional food products. In future, more formulations, upgraded technology, and more attributes should be required for commercial application in the market.

Contribution Statement

Rudro Deb Sardar: Conceptualization, Methodology, Investigation, Data collection, Formal analysis; Md. Musa Abdullah: Methodology, Data collection, Formal analysis; Enam Ahmed: Writing original draft, Review the manuscript, Validation; Md. Abdul Alim: Supervision, Project administration, Resources.

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Declaration of interest

The authors declare that there exist no competing interests regarding the publication of this research work.

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