

# Incorporation of Chia Seeds as a Functional Ingredient in the Fortification of Apple Jam

Anam Matloob<sup>1</sup>, Muhammad Atif Randhawa<sup>1\*</sup>, Hafiz Muhammad Jawad Saleem<sup>1</sup>

<sup>1</sup>National Institute of Food Science & Technology, University of Agriculture, Faisalabad, Pakistan  
anammatloob25@gmail.com; atifrandhawa@uaf.edu.pk; jawadsaleem.ft@gmail.com

**\*For correspondence:** atifrandhawa@uaf.edu.pk

**Received:** 11 December 2025    **Accepted:** 12 February 2026    **Published:** 05 March 2026

---

## ABSTRACT

---

Jams are semi-solid food items made from seasonal fruits, but they often contain fewer nutrients as a result of thermal treatment. Nutraceuticals, like chia seeds, can help address this issue by fortifying jam with phytochemicals and tocopherols. This study aimed to make chia seed-fortified apple jam and assess its physical, chemical, and sensory properties as well as storage stability. Five different types of apple jam were developed, starting with the fundamental formulation (control), which contains no chia seeds. The other four jams included 5g, 10g, 15g, and 20g of chia seed. The protein content increased from 0.41% to 6.61%, while fiber content increased from 2.81% to 14.02%. Sensory evaluation of samples was done using a 9-point hedonic scale by a panel of 5 expert persons. The chia seed-fortified apple jam sample was dark, moderate red compared to the control sample's bright orange color. The results of this study proved that the addition of chia seeds does not have a significant influence on the value of pH. Chia seeds do not have a significant effect on °Brix and the titratable acidity value of jam. The values of titratable acidity and total phenolic content increased with the length of storage duration. Chia seeds help to lower bacterial load in the product. Chia seeds fortified apple jam exhibits good storage stability during 2 months of study. The findings suggest that apple jam fortified with chia exhibits good sensory qualities that can be used for jam production and other processed products to take advantage of the functional components in chia seeds.

**Keywords:** *Salvia hispanica*, Fortification, Apple, Malnutrition, Functional foods.

## Introduction

Jam is a semi-solid food product made from different fruits by cooking and containing sugar, pectin, and other ingredients. Jams are well known for their accessibility, affordability, and sensory qualities. They are typically canned and packed in clean vessels post-production (Muresan et al., 2014). Jams are processed to the appropriate consistency. Fruits often contain considerable pectin and acid content, which are extracted while processing, resulting in the production of the jam's textural attributes. Artificial pectin is added to the jam to reach the basic 1% pectin requirement, and external sources of acids are also added to meet the required pH. High-calorie jam has a total dissolved solids content of less than 50%, reduced-calorie jam has an entire dissolved solids content of up to 45%, and low-calorie jam should have a total dissolved solids content of more than 20% without the inclusion of sugar (Shinwari and Rao, 2018). After the fruits have been chopped and processed with various additives to the desired consistency, the jam is placed in sterile containers (Nduko et al., 2018). Jams often come in two varieties: the first is made from the puree of one fruit, whereas the other is made by combining the puree of two or maybe more fruits. Glucose slows the proliferation of microbes and keeps jams from spoiling. Sugar absorbs water, extending the storability of items (Nduko et al., 2018).

The most common tree fruit in the world, the apple, originated in Southwestern Asia. Apples (*Malus domestica*) are a significant source of phytochemicals and tocopherols (Brown, 2012). Apples contain 84.7% water and many phytonutrients and vitamins (Shah et al., 2015). Apples have the potential to prevent gastrointestinal malignancies, colorectal and hepatic malignancies, myocardial infarction, and breathing problems due to their diversified and quite well-constituted nature (Feliciano et al., 2010). Jams often contain less vitamin C because of the thermal treatment. Fortifying jam with nutraceuticals is one method for addressing this issue. Dietary supplementation can restore nutrients that were wasted through cooking or improve the wholesomeness of food by including micronutrients that are not already present in them (Naem et al., 2017). Biofortification is an essential nutrition strategy to combat malnutrition and lower its prevalence in several low and moderate-income nations (Chadare et al., 2019).

Undernutrition, a severe health issue, is frequently caused by a lack of micronutrients, particularly in underdeveloped nations (Ramakrishnan et al., 2011). One of the most effective strategies to combat malnutrition caused by undernutrition is dietary supplementation (Bhagwat et al., 2014). As more individuals are becoming conscious of the dietary and physiological benefits of proteins, there is a massive rise in their need, particularly for the human diet. Plant proteins are popular due to their greater availability in nature, reduced production costs, and alignment with consumers' preferences based on nutritional requirements. In business, there is a growing interest in discovering proteins from alternative sources with superior functionalities. Because of their high abundance, digestibility, and favorable amino acid composition, seed proteins are gaining increasing attention (Timilsena et al., 2016). Beyond just providing basic nutritional needs, functional food ingredients offer physiological advantages and lower the risk of long-term illness (Ansari and Kumar, 2012). Chia seeds (*Salvia hispanica*) are just one of the foods with organic material. These seeds are uncooked, easy to consume, and contain the most significant amount of  $\alpha$ -linolenic acid, up to 67.99% (Porras-Loaiza et al., 2014). Seeds have a higher protein content than other cereals, roughly 19–23% (Sandoval-Oliveros and Paredes-López, 2013). A suitable amount of essential amino acids is also present in chia seeds, including up to 42.2–42.9% of valine, leucine, and isoleucine. Seeds contain a greater percentage of essential amino acids than

popular oil seeds like soy and sunflower. Non-essential amino acids like glutamic and aspartic acids are also abundant in chia seeds. Glutamic acid is thought to be an essential amino acid in food and improves sports performance (Olivos-Lugo et al., 2010). These also include significant levels of vitamins and minerals, as well as up to 41% of carbohydrates, 30% of fiber, 25% of proteins, and tocopherols that combat free radicals. These have no trans fatty acids or saturated fats (Timilsena et al., 2016).

Chia (*Salvia hispanica*) seeds are also used as a supplementary component in a variety of recipes made using packaged foods. The growing desire for better health and the rising prevalence of conditions, including overweight, type II diabetes, and CVD, are contributing to the rapid global growth of the chia seed (Coelho and de las Mercedes Salas-Mellado, 2015). It can also be used in jams, yogurt, fruit drinks, biscuits, and morning cereals (Attalla and El-Hussieny, 2017). Regular fruit jam is simple to spread and has a vivid color, pleasant fruit flavor, and a semi-solid texture, with no free fluid. It has uniform smoothness and no noticeable fruit fragments. Thus, fortification may alter the product's taste, flavor, physical appearance, and general acceptability by adding grit and bitterness. Fortification is delicate when a product's texture, like jam, must be maintained (Nduko et al., 2018). An appropriate balance of citric acid is necessary for making jam. Due to its higher citric acid content, lemon juice can be used in jam manufacturing as a substitute for citric acid (Ullah et al., 2018).

The objectives of this study were to develop chia seed fortified apple jam and to evaluate the nutritional and sensory properties of chia seed fortified apple jam. Chia seeds were added to apple jam as a fortifier, and their sensory qualities and desirability were assessed. Consequently, various chia seed proportions were combined to make apple jam. The prepared jam sensorial and proximate assessments showed that apple jam can be fortified with chia seeds.

## Materials & Methods

### Material and reagents

Superior quality chia seeds were obtained from the local market of Faisalabad. Apples, sugar, and other required raw materials were also obtained from the local market of Faisalabad, Pakistan. Reagents were used for TPC, protein, fiber, and equipment used in different analyses obtained from the laboratories of the National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan.

### Preparation of chia seed fortified apple jam

Apple jam was prepared by the method described by Lee (Lee, 2014). Three independent jam batches were prepared for each treatment, and each analysis was performed in triplicate. For controlled jam, 1kg of sliced apples was taken, 100mL water, 10g of pectin, and 1kg of sugar were added, and pulp was cooked until the desired consistency was achieved. Citric acid and benzoic acid were added to the jam, and chia seeds were added for the other four treatments. Chia seeds were added in amounts of 5g, 10g, 15g, and 20g per 100g of the jam sample. Storage study done at the intervals of 0, 20, 40, and 60 days.

Table 1: Treatment Plan of Apple Jam Fortified with Chia Seeds

Treatment	Jam Formulation	Chia Seeds (g/100g)
T0	100% Apple Jam	0
T1	95% Apple Jam + 5% Chia	5
T2	90% Apple Jam + 10% Chia	10
T3	85% Apple Jam + 15% Chia	15
T4	80% Apple Jam + 20% Chia	20

## Quality analysis of chia seeds fortified apple jam

### pH and Brix determination

Total soluble solids of apple jam were measured according to the method described by Ullah et al. (Ullah et al., 2018) using a digital refractometer. pH of the apple jam was measured using a pH meter following the standard method described by Kanwal et al. (Kanwal et al., 2017). The pH meter was calibrated with a buffer solution for precise results.

### Determination of titratable acidity

Total titratable acidity of the jam was determined by the method described by Emelike and Akusu (Emelike and Akusu, 2019). The sample was homogenized, and phenolphthalein indicator was added and titrated against 0.1N NaOH until a light pink color appeared. The following formula was used to compute titratable acidity:

$$\text{Total Titratable acidity} = \frac{(V)(N \times \text{Meq.wt})}{\text{wt. of sample}} \times 100$$

### Determination of moisture content

Moisture content of apple jam fortified with chia seeds was determined by using the hot air oven method (Bekele et al., 2020). Pre-dried china dishes were weighed, and a 5g sample of apple jam was heated for 24 hours in a hot air oven, then placed in a desiccator and allowed to cool to ambient temperature. Moisture content was calculated using the following formula:

$$\text{Moisture Content (\%)} = \frac{\text{Weight loss of sample (g)}}{\text{Sample weight (g)}} \times 100$$

### Determination of protein content

Protein assay was determined by the method described by Bekele et al. (Bekele et al., 2020). Heat was applied to the digesting block until it reached the proper temperature. 0.1g of the sample was used to fill the digesting tubes with 5g of catalyst and 20mL of pure sulfuric acid. After an hour-long digesting process, the sample was given five to ten mins to cool, and 40mL of distilled water was put into a measuring cylinder. The process was distilled for 4 mins in a Kjeldahl tube containing 40mL of distilled water. A conical flask containing 60mL of boric

acid solution was filled, and 2–3 drops of the indicator solution mixture were added. Sample tubes were positioned, and distillation continued until finished. 70mL of a 50% NaOH solution was then steam distilled for 4 mins. A blank run was performed with 40mL of distilled water. Samples were titrated with 0.1N HCl until the original hue was achieved, then 0.05 H<sub>2</sub>SO<sub>4</sub> was needed to cause the color shift. A blank run was conducted to remove any N, allowing for the determination of the amount of acid solution needed. The following formula is used for calculation:

$$\% \text{Nitrogen} = \frac{\text{Normality of H}_2\text{SO}_4 (0.1) \times (\text{mL acid for sample} - \text{blank}) \times 14 \times 100}{\text{Weight of sample} \times 1000}$$

$$\% \text{ Crude protein} = \% \text{N} \times \text{conversion factor (6.25)}$$

### Determination of fiber

The dietary fiber of apple jam fortified with chia seeds was determined by Naeem et al. (Naeem et al., 2017). A Megazyme kit was used to determine dietary fiber. Samples were heated at 100°C with heat-stable alpha amylase for 30–40 mins, and then incubated with protease and amyloglucosidase for hydrolysis. Ethanol was used to depolymerize and remove protein and glucose from starch. Residue was filtered and dried until constant weight. Dietary fiber was calculated by weighing the filtered residue and deducting the weight of protein and ash.

### Total phenolic content (TPC)

The sample was prepared by dilution in 70% methanol and centrifuged for 10 mins at 3500 rpm and kept at 18°C. The Folin-Ciocalteu reagent was used to determine the total phenolic content of a sample using 0.5mL of jam, 2.5mL of Folin-Ciocalteu reagent, and 2mL of sodium carbonate solution. The absorbance at 765nm was estimated using a spectrophotometer, and gallic acid equivalents were calculated (Lafarga et al., 2018).

### Total plate count

Microorganism growth is an essential factor in food spoilage, measured by plate count (Krishnaiya et al., 2016). The media nutrient agar was prepared by dissolving 7g in 250mL of distilled water, then sterilized in the hot air oven and cooled to 45°C. The four samples were diluted by pipetting, and 1mL of each sample was added to 9mL diluted water in a test tube. 20mL of cooled molten agar was placed into the Petri dish and gently swirled to distribute the inocula. After allowing the medium to harden, the plate was inverted and incubated at 30°C for 48 h. The results were then converted to CFU/g (colony-forming units per gram).

$$\text{CFU/g} = \frac{\text{No. of Colonies} \times \text{Dilution factors}}{\text{Volume of sample used}}$$

## Sensory evaluation

Sensory evaluation of samples was done using a 9-point hedonic scale by 50 expert persons from the National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan. The parameters evaluated were color, flavor, aroma, texture, taste, spreadability, syneresis, and overall acceptability (Meilgard et al., 2016).

## Statistical analysis

Minitab 18.1, a statistical program (two-way ANOVA), was used to analyze the raw data to determine the significant difference between the values (Montgomery, 2017).

## Results

### Jam preparation

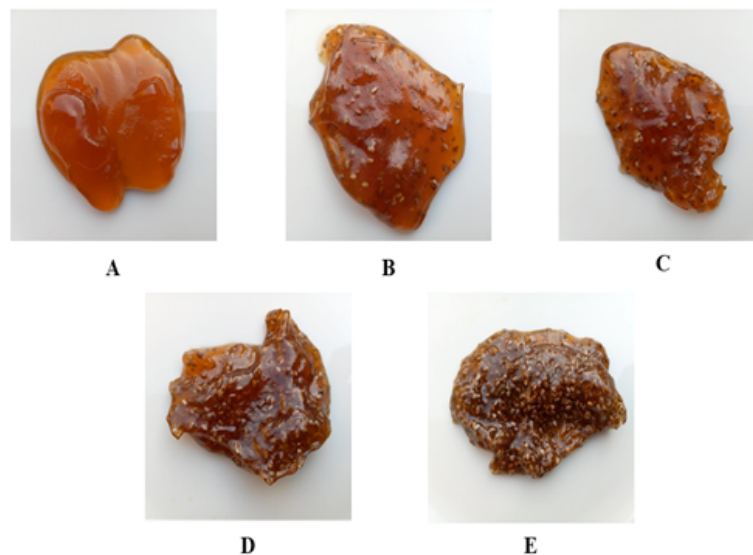


Figure 1: Pictures of chia seed fortified apple jam. A (control), B (5g), C (10g), D (15g), and E (20g) chia seeds

The pictorial images of apple jam created with apple fruit pulp, sugar, pectin, and chia seeds are shown in Fig. 1. The chia seed fortified apple jam sample is dark, moderate red compared to the control sample's bright orange color.

The results of total plate count (TPC), pH, titratable acidity, and total soluble solids (TSS) are presented in Table 2. According to statistical analysis, there were significant differences among all treatments ( $p < 0.05$ ).

Table 2: Physicochemical and microbial analysis of chia seed fortified apple jam

Trial	Amount of chia seeds (g)	Brix (°)	pH	Titratable acidity	TPC (log CFU/mL)
T0	0	67.82±0.18a	3.42±0.10b	0.53±0.02a	9.20±0.02a
T1	5	68.67±0.23a	3.16±0.05d	0.50±0.01a	6.63±0.02d
T2	10	67.88±0.30a	3.19±0.01cd	0.49±0.01a	6.40±0.01e
T3	15	67.88±0.31a	3.36±0.05bc	0.48±0.02a	7.12±0.02c
T4	20	68.54±0.83a	3.65±0.05a	0.49±0.04a	7.95±0.01b

Results are expressed as mean  $\pm$  standard deviation of three replicates. Different superscript letters within a column indicate significant differences at  $p < 0.05$ .

### pH and Brix

The jam samples fortified with chia seeds ranged in pH from 3.16 to 3.65 compared to the sample without any chia seeds (control), which had a pH of 3.42. Among all the treatments, T1 showed lower pH values, which were 3.16 (Table 2). The chia seed-fortified sample had a Brix value of 68.67–68.54° compared to the control sample's Brix of 67.82°. Among all the treatments, T0 showed lower values of °Brix, which was 67.82° (Table 2). There were no significant changes in the °Brix during the storage study of 2 months, but the pH value decreased during the storage period. The lowest value of pH recorded for jam was 3.11 for T2 at day 60.

### Titratable acidity

The jam samples fortified with chia seeds ranged in titratable acidity from 0.49 to 0.50 compared to those without chia seeds (control), which had titratable acidity of 0.53. Among all the treatments, T3 showed lower titratable acidity values, which were 0.48 (Table 2). Titratable acidity increased with the storage period. The highest value of titratable acidity recorded for jam was 0.56 for T4 at day 60.

### Total plate count

As measured by plate count, microorganism proliferation significantly contributed to food spoilage. The jam samples without chia seeds have a TPC of 9.20 (log CFU/mL), while samples fortified with chia seeds ranged in TPC from 6.63 to 7.95 (log CFU/mL). Among all the treatments, T2 showed lower values of TPC (bacterial count), which was 6.40 (log CFU/mL) (Table 2). TPC of jams increases with the length of storage period; the highest value of TPC recorded for jam was 8.99 (log CFU/mL) for T0 at day 60.

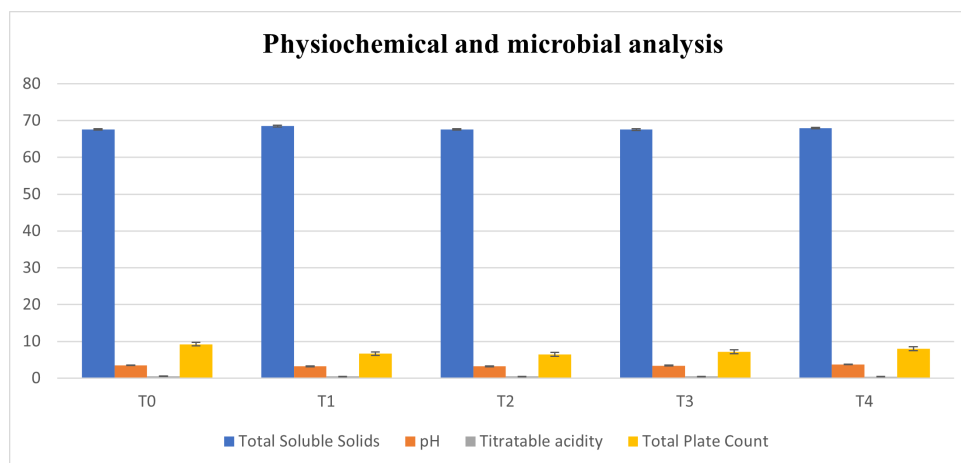


Figure 2: Physicochemical and microbial analysis of chia seed fortified apple jam

## Protein

Apple jam (control) had a total protein content of 0.41%, while the protein content of the other four jams fortified with chia seeds ranged from 1.61% to 6.61%, depending on how many chia seeds were used. One-way ANOVA was used to determine how the protein content varied. Tukey's HSD test revealed that the protein concentration of each jam composition varied significantly (Table 3).

Table 3: Proximate and antioxidant analysis of chia seed fortified apple jam

Trial	Amount of chia seeds (g)	Protein (%)	Fiber (%)	Moisture (%)	TPC (mg GAE/L)
A	0	0.41±0.01e	2.81±0.01e	30.48±0.00a	120.72±0.34e
B	5	1.61±0.01d	4.01±0.01d	29.51±0.01b	172.70±0.25d
C	10	3.72±0.02c	6.24±0.01c	29.48±0.00c	211.90±0.06c
D	15	5.04±0.01b	9.52±0.01b	28.75±0.01d	219.50±0.49b
E	20	6.61±0.01a	14.02±0.02a	28.68±0.00e	282.61±0.41a

Results are expressed as mean ± standard deviation of three replicates. Different superscript letters within a column indicate significant differences at  $p < 0.05$ .

## Fiber

The jams that had chia seeds-fortified jams had a higher fiber content overall. Apple jam (control) had a total fiber content of 2.81%, while the fiber content of the other four jams fortified with chia seeds ranged from 4.01% to 14.02%. One-way ANOVA was used to determine how the fiber content varied. Tukey's HSD test revealed that the fiber concentration of each jam composition varied significantly (Table 3).

## Moisture

The jam samples fortified with chia seeds ranged in moisture content from 29.51% to 28.68% compared to the sample without any chia seeds (control), which had a moisture content of 30.48%. Among all the treatments, T4 showed lower values of moisture percentage, which was 28.68% (Table 3).

## Total phenolic content

In comparison to the jam sample without any chia seeds (control), which had a total phenolic content of 120.72 mg GAE/L, the jam samples fortified with chia seeds ranged in total phenolic content from 172.70 to 282.61 mg GAE/L. T4 outperformed the other treatments in terms of total phenolic content, with a value of 282.61 mg GAE/L (Table 3). Total phenolic content of jams increased with the length of storage period; the highest value of TPC recorded for jam was 283 mg GAE/L for T4 at day 60.

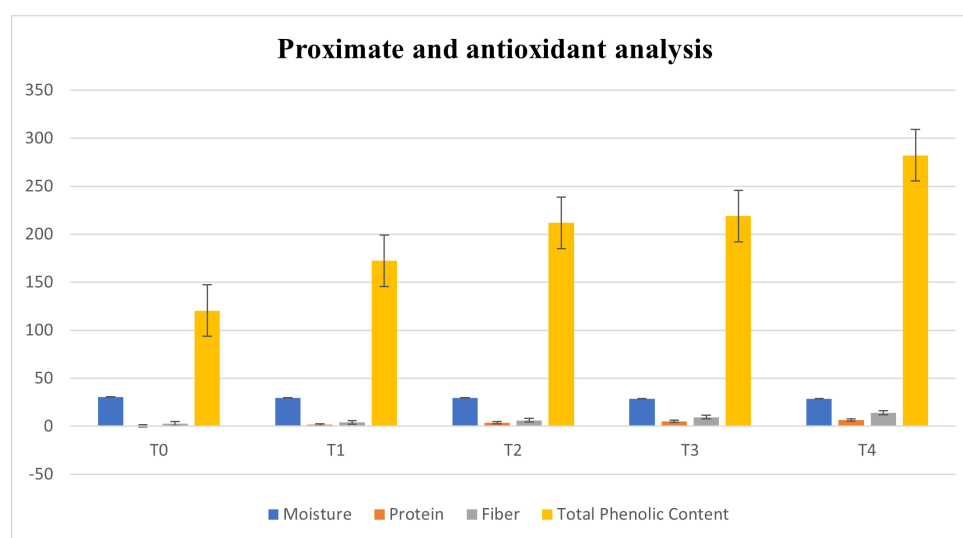


Figure 3: Proximate and antioxidant analysis of chia seed fortified apple jam

## Sensory analysis

Table 4 demonstrates how adding chia seeds significantly altered the sensory qualities assessed by the tasting panel. The addition of 10g of chia seeds did not dramatically modify the color or texture of the jam, according to the results, but adding more chia seeds led to noticeable modifications. On the other hand, adding chia seeds to the jam had a minimal impact on the spreadability of the jam but had a significant effect on the flavor and general acceptance of the jam. The sensory quality of the jam was negatively impacted by adding chia seeds at rates of 15g and 20g per 100g of the jam sample. T2, however, showed promising outcomes in terms of overall acceptability.

Table 4: Sensory analysis of chia seed fortified apple jam

Attributes/Trials	A	B	C	D	E
Aroma	7.62±0.01b	7.63±0.02b	8.10±0.10a	7.57±0.21b	6.83±0.03c
Flavor	8.20±0.00b	7.83±0.05c	8.61±0.01a	6.24±0.05d	5.26±0.05e
Color	8.23±0.03b	8.25±0.05b	8.83±0.03a	6.42±0.04c	6.13±0.15d
Taste	8.20±0.00b	8.20±0.00b	8.61±0.01a	6.24±0.05c	5.81±0.01d
Texture	8.23±0.03b	8.25±0.05b	8.42±0.02a	6.03±0.06c	4.81±0.02d
Spreadability	8.03±0.05b	8.10±0.17ab	8.33±0.30a	6.83±0.05c	5.28±0.07d
Syneresis	8.25±0.05c	8.42±0.02b	8.98±0.03a	7.06±0.05d	8.25±0.05c
Overall acceptability	8.03±0.05c	8.42±0.02b	8.83±0.03a	6.03±0.06d	4.24±0.05e

Sensory scores are presented as mean ± SD. Different superscript letters within a row indicate significant differences at  $p < 0.05$ . Trials A, B, C, D, and E represent control, 5g, 10g, 15g, and 20g chia seeds added per 100g of jam sample, respectively.

## Discussion

Jams are widely consumed due to their low cost, year-round availability, and organoleptic qualities, and various fruits are utilized in their production (Baker et al., 2005). According to the spreadability ratings of the formed jams, the chia seed inclusion did not affect how the jam gelled. The protein content of the control jam was 0.41%, comparable to the displayed protein content of 0.06% (Ahmed et al., 2015). The protein content of apple jam is low because common ingredients used in the production of jam are not a good source of protein, including pectin, sugar, fruits, benzoic acid, and citric acid. The inclusion of chia seeds in apple jam increases the protein content. Chia seeds are a good source of protein (16.5%), and their protein value is higher than most cereal group foods (Valdivia-López and Tecante, 2015). Chia seeds are a worthy source of essential and non-essential fatty acids (Kulczyński et al., 2019). Chia seeds can be used to fortify low-protein foods like apple jam. One more valuable component of chia seeds is their high fiber content, and they also contain many bioactive components, making them a superfood. The addition of chia seeds to apple jam also increased the jam's fiber content. Chia seeds include both insoluble fibers, which make up the majority of the diet, and soluble dietary fiber, which is fermented in the colon (Anderson et al., 2009). Dietary fiber facilitates efficient digestion, which facilitates bowel movement and has numerous positive health effects (Satija and Hu, 2012). The incorporation of chia seeds in apple jam endows it with advantageous functional ingredients since the presence of the essential fatty acids, particularly  $\alpha$ -linolenic acid (Marcinek and Krejpcio, 2017). The results of this study have proved that the addition of chia seeds does not have a significant influence on the value of pH. The pH is an important factor in the gel formation of jam. Like pH, chia seed do not significantly affect the °Brix and titratable acidity value of jam. The values of pH decreased with the increase of storage period while the values of titratable acidity increased. Chia seeds are a good source of antioxidants, which is why they help to lower bacterial load in the product. The values of total plate count and total phenolic content increased with the increase of storage period. Color and texture are important sensory qualities that influence consumer approval. Chia seed additions of 5g and 10g did not appreciably change the product's color or texture, proving that higher chia seed dosages could not be tolerated.

The use of whole chia seeds may have contributed to the low scores for the texture where chia seeds were used in higher concentrations. Although chia seeds have a mild flavor, they do not have significant impact on the jam's flavor. This might be explained by perception as a result of the jam's new ingredient, which consumers might not be familiar with. Spreadability was unaffected, which may have been because chia seeds formed a viscous solution. Chia seed have gel-forming ability which is beneficial in the development of perfect jam (Segura-Campos et al., 2014). General acceptability indicated that T2 was the most preferred chia seed-fortified jam. Apple jam fortified with low levels of chia seeds gains acceptability from consumers while jams containing higher concentration of chia seeds was not acceptable. Chia seeds fortified apple jam exhibit good storage stability during 2 months of study. Chia seed product development is highly desirable in the food industry and has the potential to be used in nutraceutical food items.

Adding chia seeds improved nutritional content; however, higher inclusion levels reduced texture acceptability, while 10 g/100 g remained acceptable (protein increased from 0.41% to 6.61%, and fiber enhanced from 2.81% to 14.02%). Consumers were less prepared to trade the sensory qualities of apple jams for the functional qualities and health advantages of chia seeds, even though chia seeds have been accepted for their functional qualities. At the outset of the product development process, this fact needs to be considered. However, adding chia seeds in smaller amounts (such as 10g) seemed to have little impact on the sensory qualities and to be better tolerated, suggesting that formula optimization is crucial for product development and raising consumer awareness of the health advantages of functional products.

## Competing Interests

The authors declare that they have no competing interests.

## Funding

No funding

## Acknowledgements

The authors are highly obliged to the University of Agriculture, Government College University Faisalabad (GCUF), the University of Lahore and IT Department, Higher Education Commission (HEC, Islamabad) for access to journals, books and valuable database.

## Author's contribution

Anam Matloob conducted the experiments and investigation and wrote the original draft. Muhammad Atif Randhawa conceptualized, supervised the research work, and proofread the manuscript. Hafiz Muhammad Jawad Saleem helped in writing this manuscript, used statistical software, and proofread the manuscript.

## References

- Ahmed, L., Islam, M. N., Islam, M. S., & Ali, M. S. (2015). Estimation of protein in jams, jellies and juices available in Bangladesh. *Science Journal of Analytical Chemistry*, 3(4), 43–46.
- Anderson, J. W., Baird, P., Davis Jr, R. H., Ferreri, S., Knudtson, M., Koraym, A., & Williams, C. L. (2009). Health benefits of dietary fiber. *Nutrition Reviews*, 67(4), 188–205.
- Ansari, M. M., & Kumar, D. S. (2012). Fortification of food and beverages with phytonutrients. *Food and Public Health*, 2(6), 241–253.
- Attalla, N. R., & El-Hussieny, E. A. (2017). Characteristics of nutraceutical yoghurt mousse fortified with chia seeds. *International Journal of Environment, Agriculture and Biotechnology*, 2(4), 238873.
- Baker, R. A., Berry, N., Hui, Y., & Barrett, D. M. (2005). Fruit preserves and jams. *Processing Fruits: Science and Technology*, 2, 112–125.
- Bekele, M., Satheesh, N., & Sadik, J. (2020). Screening of Ethiopian mango cultivars for suitability for preparing jam and determination of pectin, sugar, and acid effects on physico-chemical and sensory properties of mango jam. *Scientific African*, 7, e00277.
- Bhagwat, S., Gulati, D., Sachdeva, R., & Sankar, R. (2014). Food fortification as a complementary strategy for the elimination of micronutrient deficiencies: case studies of large scale food fortification in two Indian States. *Asia Pacific Journal of Clinical Nutrition*, 23, pS4.
- Brown, S. (2012). *Apple*. Springer.
- Chadare, F. J., Idohou, R., Nago, E., Affonfere, M., Agossadou, J., Fassinou, T. K., & Linnemann, A. R. (2019). Conventional and food-to-food fortification: An appraisal of past practices and lessons learned. *Food Science & Nutrition*, 7(9), 2781–2795.
- Coelho, M. S., & de las Mercedes Salas-Mellado, M. (2015). Effects of substituting chia (*Salvia hispanica* L.) flour or seeds for wheat flour on the quality of the bread. *LWT-Food Science and Technology*, 60(2), 729–736.
- Emelike, N., & Akusu, O. (2019). Quality attributes of jams and marmalades produced from some selected tropical fruits. *Journal of Food Processing & Technology*, 10(5), 1–7.
- Feliciano, R. P., Antunes, C., Ramos, A., Serra, A. T., Figueira, M., Duarte, C. M., & Bronze, M. R. (2010). Characterization of traditional and exotic apple varieties from Portugal. Part 1–Nutritional, phytochemical and sensory evaluation. *Journal of Functional Foods*, 2(1), 35–45.
- Kanwal, N., Randhawa, M., & Iqbal, Z. (2017). Influence of processing methods and storage on physico-chemical and antioxidant properties of guava jam. *International Food Research Journal*, 24(5), 2017–2027.
- Krishnaiya, R., Kasar, C., & Gupta, S. (2016). Influence of water chestnut (*Trapa natans*) on chemical, rheological, sensory and nutritional characteristics of muffins. *Journal of Food Measurement and Characterization*, 10, 210–219.

- Kulczyński, B., Kobus-Cisowska, J., Taczanowski, M., Kmiecik, D., & Gramza-Michałowska, A. (2019). The chemical composition and nutritional value of chia seeds—Current state of knowledge. *Nutrients*, 11(6), 1242.
- Lafarga, T., Aguiló-Aguayo, I., Bobo, G., Chung, A. V., & Tiwari, B. K. (2018). Effect of storage on total phenolics, antioxidant capacity, and physicochemical properties of blueberry (*Vaccinium corymbosum* L.) jam. *Journal of Food Processing and Preservation*, 42(7), e13666.
- Lee, S.-M. (2014). Quality characteristics of apple jam added with ginger. *Culinary Science and Hospitality Research*, 20(2), 79–88.
- Marcinek, K., & Krejpcio, Z. (2017). Chia seeds (*Salvia hispanica*): health promoting properties and therapeutic applications—a review. *Roczniki Państwowego Zakładu Higieny*, 68(2), 123–129.
- Meilgard, M., Civile, G., & Carr, B. (2016). *Sensory Evaluation Techniques*. CRC Press Taylor & Francis Group, Boca Raton London.
- Montgomery, D. C. (2017). *Design and analysis of experiments*. John Wiley & Sons.
- Muresan, C., Pop, A., Muste, S., Scrob, S., & Rat, A. (2014). Study concerning the quality of jam products based on banana and ginger. *Journal of Agroalimentary Processes and Technologies*, 20(4), 408–411.
- Naeem, M. M., Fairulnizal, M. M., Norhayati, M., Zaiton, A., Norliza, A., Syuriahti, W. W., & Rusidah, S. (2017). The nutritional composition of fruit jams in the Malaysian market. *Journal of the Saudi Society of Agricultural Sciences*, 16(1), 89–96.
- Nduko, J. M., Maina, R. W., Muchina, R. K., & Kibitok, S. K. (2018). Application of chia (*Salvia hispanica*) seeds as a functional component in the fortification of pineapple jam. *Food Science & Nutrition*, 6(8), 2344–2349.
- Olivos-Lugo, B. L., Valdivia-López, M. Á., & Tecante, A. (2010). Thermal and physicochemical properties and nutritional value of the protein fraction of Mexican chia seed (*Salvia hispanica* L.). *Food Science and Technology International*, 16(1), 89–96.
- Porrás-Loaiza, P., Jiménez-Munguía, M. T., Sosa-Morales, M. E., Palou, E., & López-Malo, A. (2014). Physical properties, chemical characterization and fatty acid composition of Mexican chia (*Salvia hispanica* L.) seeds. *International Journal of Food Science & Technology*, 49(2), 571–577.
- Ramakrishnan, U., Goldenberg, T., & Allen, L. H. (2011). Do multiple micronutrient interventions improve child health, growth, and development? *The Journal of Nutrition*, 141(11), 2066–2075.
- Sandoval-Oliveros, M. R., & Paredes-López, O. (2013). Isolation and characterization of proteins from chia seeds (*Salvia hispanica* L.). *Journal of Agricultural and Food Chemistry*, 61(1), 193–201.
- Satija, A., & Hu, F. B. (2012). Cardiovascular benefits of dietary fiber. *Current Atherosclerosis Reports*, 14, 505–514.

- Segura-Campos, M. R., Ciau-Solís, N., Rosado-Rubio, G., Chel-Guerrero, L., & Betancur-Ancona, D. (2014). Chemical and functional properties of chia seed (*Salvia hispanica* L.) gum. *International Journal of Food Science*, Article ID 241053.
- Shah, W., Khan, A., Zeb, A., Khan, M., Shah, F., Amin, N., & Khan, S. (2015). Quality evaluation and preparation of apple and olive fruit blended jam. *Global Journal Medical Research: L Nutrition and Food Science*, 15(1), 1–8.
- Shinwari, K. J., & Rao, P. S. (2018). Stability of bioactive compounds in fruit jam and jelly during processing and storage: A review. *Trends in Food Science & Technology*, 75, 181–193.
- Timilsena, Y. P., Adhikari, R., Kasapis, S., & Adhikari, B. (2016). Molecular and functional characteristics of purified gum from Australian chia seeds. *Carbohydrate Polymers*, 136, 128–136.
- Ullah, N., Ullah, S., Khan, A., Ullah, I., & Badshah, S. (2018). Preparation and evaluation of carrot and apple blended jam. *Journal of Food Processing & Technology*, 9(4), 725.
- Valdivia-López, M. Á., & Tecante, A. (2015). Chia (*Salvia hispanica*): A review of native Mexican seed and its nutritional and functional properties. *Advances in Food and Nutrition Research*, 75, 53–75.