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Harnessing the Potential of Stevia (*Stevia rebaudiana*) and Chia Seed (*Salvia hispanica*) on Low-calorie Papaya (*Carica papaya* L.) Jam Formulation and Storage Optimization

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Abstract

The quality of jam is significantly impacted by the storage conditions. The present study addresses the imperative need for a nutritious and low-calorie fruit preserve by focusing on the development of an unconventional low-calorie papaya (*Carica papaya* L.) jam with enhanced nutritional qualities, and extended shelf-life by substituting sucrose with natural sweeteners Stevia (*Stevia rebaudiana*) and Chia Seed (*Salvia hispanica*) as a functional ingredient. Incorporating these natural sweeteners and functional ingredients is anticipated to improve the nutritional properties of jam while also addressing health issues linked to traditional high-sugar jams. Through a comprehensive investigation of the formulation, this research aims to elucidate the impact of stevia and chia seed on the product's nutritional value. Various low calorie papaya jam samples were formulated using nineteen different treatments. These jams were stored in pre-sterilized glass jars at ambient temperature. All nutritional aspects of these samples were as *Carica papaya* sessed at two-month intervals over a period of six months. Results revealed that during the storage crude fibre value increased by (5.18 %-5.38 %) and crude fat content (0.78 %-0.82 %). Other end, moisture content dropped by (29.01 %-25.09 %), water activity (a_w) (0.73-0.70), ash content (1.65 %-1.57 %), crude protein content (3.65 %-3.55 %), antioxidant activity (30.62 %-27.46 %), total flavonoid content (43.70 %-41.78 %) and total phenolic content (56.43 %-52.55 %), respectively. The nutritional evaluation depicted that the jam sample prepared with stevia @ 10gm/kg + chia seed @ 6.25%/kg + potassium metabisulphite @ 100mg/kg was considered best and demonstrated stability minimum for up to six months

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of storage, during which this period only minor changes observed in the nutritional characteristics and sensory ratings.

Introduction

The papaya (*Carica papaya* L.) is a vital crop in tropical and subtropical regions, part of Caricaceae family with 31 species across 4 genera.[1] Originating from tropical America, particularly southern Mexico and Central America.[2] Papaya is extensively cultivated in countries i.e. India, Brazil, Indonesia, Nigeria, and Mexico. Mexico holds the top position in global export, capturing 55% of the market, while India leads in production, contributing 48% of the global yield, with 149,000 hectares in India yielding 5,744,000 metric tons.[3, 4] Papaya is globally esteemed for its nutritional and medicinal properties, comprising dietary fibers, proteins, minerals, and vitamins, alongside a variety of plant-derived phytonutrients including, enzymes like papain and chymopapain, glycosides, phytosterols and flavonoids, which possesses anti-fungal, anti-fertility, anti-microbial, anthelmintic, anti-malarial, immunomodulatory, anti-amoebic, and hepatoprotective effects.[5, 6] Papaya is consumed worldwide in various forms, including raw as vegetable, and ripe for snacks, milkshakes, medicine, juice, pies, jams, and jellies.[7, 49]

Jam, a popular convenient breakfast option is a semi-moist food, combines fruit pulp, pectin, sugar, acid and optional additives like flavors and colors cooked prior to thickened.8 Due to limited preservation facilities, perishable raw fruits are preserved as jams and jellies, reducing post-harvest losses.[2] Fruit processing, including jam-making, supports the food industry and farmers economically.[9] Sugar, from cane or beets, sweetens jam for better taste, color, and flavor, inhibits microbial growth by binding water but also led to health issues such as obesity, diabetes, and high cholesterol etc.[10] Yet, concerns about high sugar consumption drive demand for low-calorie jams sweetened with alternative sweeteners.[11] Sugar substitutes, such as synthetic sweeteners, are frequently used in making low-calorie products. However, they pose health risks like fatigue and potential mental health concerns over extended usage. Hence, there's an increasing need for natural non-caloric sweeteners alternatives.[12]

Stevia (*Stevia rebaudiana* Bertoni), a natural non-caloric sweetener from the Asteraceae family, is valued for its steviol glycosides, which are 100-300 times sweeter than sucrose.[13, 50] Increasingly favored as a natural sugar substitute due to its rich array of bioactive compounds, including protein, fiber, minerals, vitamins, and phenolic acids, endows it with antioxidant, hypoglycemic, hypotensive, and antimicrobial properties.[14] Unlike artificial sweeteners, stevia is non-toxic and entirely safe, preserving the texture, viscosity, and appearance of processed foods without altering sensory characteristics. Its multifaceted benefits position it as a principal source of high-intensity sweeteners in the expanding natural food sector.[15]

Fruits, including grapes, are primary sources of phenolic compounds like anthocyanin's and flavonols in the diet, suggesting potential for fruit juices to serve as functional ingredients in the food industry.[16, 51-53] Grapes (*Vitis vinifera*), part of vitaceae family, are abundant in natural sugars, vitamins, minerals, and acting as potent antioxidants with demonstrated health benefits including cardio-protection, anti-inflammatory effects etc.[17] Grape juice, therefore, holds promise as a functional ingredient, particularly in products like jams, where combining fruits can enhance nutritional value and elevate overall quality.[18]

Additionally, this research delved into investigating Chia seed (*Salvia hispanica* L.) and Gum Tragacanth (GT) (*Astragalus* spp.) as potential substitutes for pectin. Chia boasts significant nutritional value, comprising 35% total dietary fibre, 16% omega-3 fatty acids, 30% total fat, and 16.5% protein.[19, 54] Gum Tragacanth (*Astragalus* spp.), meets consumer preferences and regulatory standards as a food additive.[20, 55] Originating mainly from Iran, GT, also known as katira, is renowned in the biomedical field.[21, 56] Chia seeds and Gum Tragacanth (GT) exhibit exceptional technological properties like water holding capacity, emulsifying, and stabilizing, attributed to their unique chemical composition.[22] This versatility enables diverse food preparations,[23] and enhances nutritional profiles while offering health benefits like improved blood lipids, blood pressure, and blood sugar alongside antioxidant, antimicrobial, antibacterial, anti-cancer, anti-inflammatory, antiaging and immune-boosting effects.[24] Commonly used in pasta, biscuits, cereals, cakes, snacks, ice cream, beverages, and pastries etc. Chia seed and GT both act as effective thickeners, creating a jam-like texture by absorbing liquid from fruits.[25]

In this current situation, the present investigation was concentrated on the preparation of nutritious low-calorie papaya jam substituting sucrose with natural sweeteners stevia and grape juice while pectin with chia seed and gum tragacanth. Study also evaluates storage stability and acceptability of replacing sucrose with a non-caloric sweetener, as well as its impact on the nutritional and sensory characteristics of low-calorie papaya jam throughout storage.

Materials and Methods

Experimental Site and Collection of Materials

This investigation was performed at the Lovely Professional University's Department of Horticulture Laboratory in the School of Agriculture in Phagwara, Punjab, India. By using ripe, fresh, and disease free papaya (*Carica papaya* L.) fruits cultivar Pusa Delicious, procured from a reliable source. In addition, stevia, grape juice, chia seeds, and gum tragacanth, were purchased from local market of Hoshiarpur, Punjab. The processing equipment's and other materials were acquired from the Food Technology and Nutrition Department.

Details of Treatments

Nineteen distinct treatments were utilized in the preparation of low-calorie papaya jam i.e. T_1: S1C0P0 (control), T_2: S2C0P0, T_3: S3C0P0, T_4: S1C0P1, T_5: S2C0P1, T_6: S3C0P1, T_7: S1C1P0, T_8: S2C1P0, T_9: S3C1P0, T_{10}: S1C1P1, T_{11}: S2C1P1, T_{12}: S3C1P1, T_{13}: S1C2P0, T_{14}: S2C2P0, T_{15}: S3C2P0, T_{16}: S1C2P1, T_{17}: S2C2P1, T_{18}: S3C2P1 and T_{19} (standard) where, (S1: No sugar; S2: Grape juice @ 30%/kg pulp, S3: Stevia @ 10gm/kg pulp; C0: No consistency material; C1: Chia seed @ 6.25%/kg pulp; C2: Gum Tragacanth @ 15%/kg pulp; P0: No preservative; P1: Potassium metabisulphite (KMS) @ 100 mg/kg pulp), with various concentrations of materials instead of sucrose and pectin. The flow diagram depicting the process of its preparation has been presented in Fig. 1.

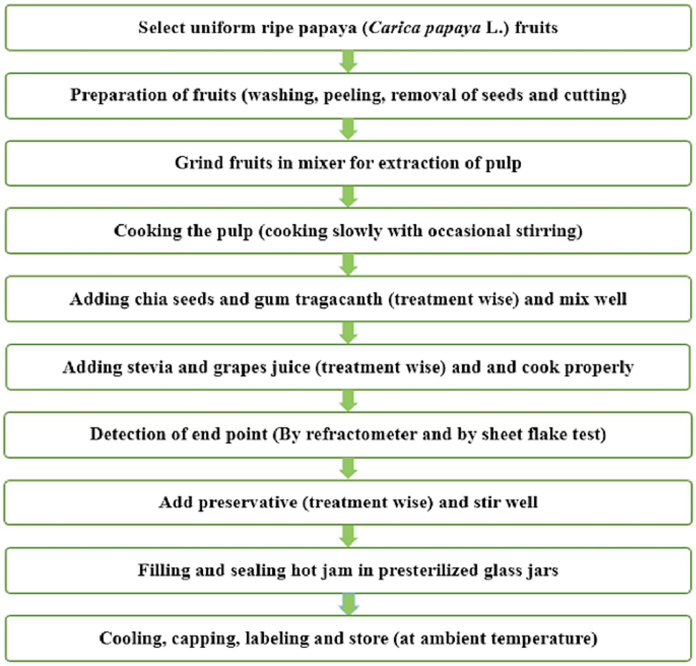

Fig. 1. Flow chart of preparation of low-calorie papaya jam

Procedure of Jam Making

Ripe, fresh papayas were washed, peeled, and cut into slices. Later, pieces were blended to create papaya puree. Ingredients for low-calorie papaya jam, including 1 kg papaya pulp, various sweeteners, thickening agents, citric acid, and 100 mg potassium metabisulphite, were carefully measured. After blending, the obtained fruit pulp was poured into a heavy bottom container and thereafter subjected to heat. When the mixture started to boil, thickening agents (gum tragacanth and chia seed) were added based on specific treatments. Sweeteners (stevia and grape juice) were added treatment-wise towards the end of the preparation, and cooked until the desired jam consistency (refractometer and sheet flake test) was achieved. The mixture's total soluble solids (TSS) were measured by a hand refractometer. The cooking was ceased, and potassium metabisulphite (KMS) was incorporated. After cooling, the final product was poured into sterilized glass jars and stored at ambient temperature for further analysis.

Observations Recorded

The nutrient profile was analyzed for both control and selected jam samples by using methodology.[26] By examining jam's ash content, crude fibre, protein content, and antioxidant activity, the nutritional profile was established. The moisture content was measured using the gravimetric method as outlined by AOAC 934.01. The protein content was measured using the Kjeldahl method (AOAC 979.09). AOAC 923.03 was used to analyse the ash content. AOAC 985.[29] was used to analyze the total dietary fibre content.[26] Water activity was determined implementing an electronic water activity meter (Model Aqualab, Japan).[27] The Total Phenolic Content (TPC) was measured employing the Folin-Ciocalteu method with a UV-VIS Lambda 25 spectrophotometer, while antioxidant activity was evaluated implementing the DPPH (2,2-Diphenyl-1-picrylhydrazyl) radical scavenging assay with a UVD-3200 UV-Vis spectrophotometer (Labomed, Inc., Culver City, USA).[28] The total flavonoid content (TFC) of samples was evaluated employing the aluminum trichloride method with a UV-Vis spectrophotometric.[29] The sensory assessment was carried out on a nine-point hedonic scale, at ambient temperature with five expert panelists.[30] Beginning on day 0 and continuing through month 6, data was collected for every parameter at two-month periods, and analyses were carried out in triplicate.

Statistical Analysis

The data gathered during the study underwent statistical analysis using SPSS v. 21 software. Subsequently, the Duncan multiple range test (DMRT) was employed to identify sets of treatments with similar characteristics, aiding in derivation of conclusions ($p<0.05$).

Results

Impact of Treatments and Storage Period on the Nutritional Attributes and Organoleptic characteristics of Low-Calorie Papaya Jam

Among the most vital components affecting a product's freshness and shelf life is moisture.[31] In low calorie papaya jam, the incorporation of stevia and chia seed had impacted significantly ($p<0.05$) the moisture content (%) throughout the treatments as well as storage (Table 1). The standard jam had an initial average moisture content of (31.53 %), which decreased to (28.61 %) during storage. Among the fresh samples, T_1 exhibited the highest moisture content (34.11 %) while sample T_{18} had the lowest (29.01 %). Throughout the storage, moisture content decreased to (32.02 %) for T_1 and (25.09 %) for T_{18}, respectively.

The water activity (a_w) plays a vital role in extending the shelf life. The inclusion of stevia and chia seed in low-calorie papaya jam had influenced significantly ($p<0.05$) on water activity (aw) throughout treatments and storage (Table 1). For standard jam sample, water activity decreased from 0.79 to 0.76. Maximum water activity at zero day was found in T_1 (0.92), while minimum reported in T_{18} (0.73). These values gradually decreased to (0.90) for T_1 and (0.70) for T_{18}, respectively during storage.

The findings of ash content (g/100g) of low-calorie papaya jam are displayed in Table 1. The ash content reveals minerals that are present in food goods. Ash content is the amount of inorganic substance that is left over after organic matter is destroyed.[32] In low calorie papaya jam, the incorporation of stevia and chia seed had impacted significantly ($p<0.05$) the ash content (g/100g) throughout the treatments as well as storage. The standard jam sample had (1.51 g/100g) ash content which dropped to (1.43 g/100g) over the course of time. Initially, T_{12} had the highest ash content of (1.65 g/100g), and T_1 had minimum ash content of (1.18 g/100g), which gradually decreased during storage to (1.57 g/100g) for T_{12}, and (1.01 g/100g) for T_1, respectively.

Table 1: Impact on moisture content, water activity and ash content of low-calorie papaya jam with Chia Seed, Stevia, Gum Tragacanth, Grape Juice and Preservative during prolonged storage

Treatments	Moisture Content (%)				Water Activity (a_w)				Ash Content (g/100g)			
	0 Day	2 Months	4 Months	6 Months	0 Day	2 Months	4 Months	6 Months	0 Day	2 Months	4 Months	6 Months
T_1	34.11_{a}	34.02^{a}	32.18^{a}	32.02^{a}	0.92^{a}	0.91^{a}	0.90^{a}	0.90^{a}	1.18^{b}	1.15^{c}	1.11^{c}	1.01^{b}
T_2	33.15_{cd}	33.09^{cd}	31.22^{bc}	31.15^{c}	0.89^{a}	0.88^{a}	0.87^{a}	0.86^{a}	1.23^{ab}	1.21^{abc}	1.16^{bc}	1.08^{ab}
T_3	33.54_{b}	33.25^{b}	31.61^{b}	31.34^{b}	0.91^{a}	0.90^{a}	0.89^{a}	0.88^{a}	1.27^{ab}	1.24^{abc}	1.20^{abc}	1.10^{ab}
T_4	34.08^{a}	32.19^{a}	31.15^{a}	30.17^{a}	0.92^{a}	0.91^{a}	0.90^{a}	0.89^{a}	1.22^{ab}	1.22^{bc}	1.17^{bc}	1.14^{ab}
T_5	33.06_{de}	31.17_{de}	30.13^{cd}	29.16^{c}	0.88^{a}	0.87^{a}	0.86^{a}	0.85^{a}	1.25^{ab}	1.24^{abc}	1.20^{abc}	1.17^{ab}
T_6	33.46_{bc}	31.57_{bc}	30.53^{b}	29.54^{b}	0.90^{a}	0.89^{a}	0.88^{a}	0.87^{a}	1.30^{ab}	1.30^{abc}	1.25^{abc}	1.22^{ab}
T_7	32.87_{def}	32.58_{def}	30.94^{cde}	30.78^{cd}	0.87^{a}	0.86^{a}	0.85^{a}	0.85^{a}	1.33^{ab}	1.31^{abc}	1.27^{abc}	1.12^{ab}
T_8	31.78_{g}	31.65_{g}	29.85^{f}	28.89^{e}	0.82^{a}	0.81^{a}	0.80^{a}	0.79^{a}	1.43^{ab}	1.40^{abc}	1.37^{abc}	1.32^{ab}
T_9	29.52_{h}	28.36_{h}	28.32^{g}	27.36^{f}	0.75^{a}	0.74^{a}	0.73^{a}	0.72^{a}	1.60^{a}	1.57^{ab}	1.54^{ab}	1.49^{ab}
T_{10}	32.74_{ef}	30.85_{ef}	29.81^{de}	28.82^{d}	0.87^{a}	0.86^{a}	0.85^{a}	0.84^{a}	1.36^{ab}	1.34^{abc}	1.31^{abc}	1.28^{ab}
T_{11}	31.70_{g}	29.81_{g}	28.77^{f}	27.80^{e}	0.81^{a}	0.80^{a}	0.79^{a}	0.78^{a}	1.45^{ab}	1.42^{abc}	1.40^{abc}	1.37^{ab}
T_{12}	29.17_{h}	27.28^{h}	26.24^{g}	25.27^{f}	0.74^{a}	0.73^{a}	0.72^{a}	0.71^{a}	1.65a	1.64^{a}	1.60^{a}	1.57^{a}
T_{13}	32.66_{f}	32.47^{f}	30.73^{de}	30.51^{d}	0.85^{a}	0.84^{a}	0.83^{a}	0.83^{a}	1.39^{ab}	1.36^{abc}	1.33^{abc}	1.19^{ab}
T_{14}	31.61_{g}	31.32^{g}	29.68^{f}	28.66^{e}	0.79^{a}	0.78^{a}	0.77^{a}	0.76^{a}	1.47^{ab}	1.45^{abc}	1.41^{abc}	1.37^{ab}
T_{15}	30.11_{h}	29.22^{h}	28.18^{g}	27.15^{f}	0.76^{a}	0.75^{a}	0.74^{a}	0.73^{a}	1.53^{ab}	1.49^{abc}	1.46^{abc}	1.41^{ab}
T_{16}	32.59_{f}	30.70^{f}	29.66^{e}	28.65^{d}	0.84^{a}	0.83^{a}	0.82^{a}	0.81^{a}	1.40^{ab}	1.40^{abc}	1.37^{abc}	1.34^{ab}
T_{17}	30.27_{h}	28.38^{h}	27.34^{g}	26.40^{f}	0.78^{a}	0.77^{a}	0.76^{a}	0.75^{a}	1.50^{ab}	1.47^{abc}	1.45^{abc}	1.42^{ab}
T_{18}	29.01_{h}	27.12^{h}	26.08^{g}	25.09^{f}	0.73^{a}	0.72^{a}	0.71^{a}	0.70^{a}	1.56^{ab}	1.55^{abc}	1.51^{abc}	1.48^{ab}
T_{19}	31.53^{g}	30.64^{g}	29.60^{f}	28.58^{e}	0.79^{a}	0.78^{a}	0.77^{a}	0.76^{a}	1.51^{ab}	1.48^{abc}	1.46^{abc}	1.43^{ab}

Mean values within the same row with different superscript lowercase letters are significantly different ($p \leq 0.05$).

Table 2: Impact on crude fiber content, crude fat content and crude protein content of low-calorie papaya jam with Chia Seed, Stevia, Gum Tragacanth, Grape Juice and Preservative during prolonged storage

Treatments	Crude Fibre Content (g/100g)				Crude Fat Content (g/100g)				Crude Protein Content (% dwb)			
	0 Day	2 Months	4 Months	6 Months	0 Day	2 Months	4 Months	6 Months	0 Day	2 Months	4 Months	6 Months
T_{1}	1.30_{d}	1.36^{d}	1.37^{d}	1.38^{d}	0.45^{c}	0.46^{c}	0.52^{b}	0.60^{b}	0.89^{j}	0.87^{j}	0.72^{i}	0.47^{h}
T_{2}	1.46_{bcd}	1.52^{bcd}	1.55^{bcd}	1.56^{bcd}	0.52^{abc}	0.53^{abc}	0.57^{ab}	0.66^{ab}	1.05^{ij}	1.03^{ij}	0.97^{hi}	0.55^{gh}
T_{3}	1.40^{bcd}	1.47^{bcd}	1.49^{bcd}	1.49^{bcd}	0.49^{abc}	0.50^{abc}	0.55^{ab}	0.63^{ab}	0.96^{ij}	0.93^{ij}	0.89^{hi}	0.62^{h}
T_{4}	1.34^{cd}	1.41^{cd}	1.44^{cd}	1.54^{cd}	0.46^{bc}	0.47^{bc}	0.49^{b}	0.50^{ab}	0.93^{j}	0.91^{j}	0.86^{hi}	0.83^{h}
T_{5}	1.48^{bcd}	1.55^{bcd}	1.58^{bcd}	1.69^{bcd}	0.53^{abc}	0.54^{abc}	0.56^{ab}	0.57^{ab}	1.08^{hij}	1.06^{hij}	1.01^{ghi}	0.98^{fgh}
T_{6}	1.42^{bcd}	1.49^{bcd}	1.52^{bcd}	1.61^{bcd}	0.50^{abc}	0.51^{abc}	0.53^{ab}	0.54^{ab}	0.99^{ij}	0.97^{ij}	0.92^{hi}	0.89^{h}
T_{7}	3.51^{bcd}	3.58^{bcd}	3.60^{bcd}	3.61^{bcd}	0.55^{abc}	0.56^{abc}	0.63^{ab}	0.72^{ab}	2.40^{cd}	2.36^{cd}	2.13^{c}	1.85^{cd}
T_{8}	3.64^{bcd}	3.71^{bcd}	3.73^{bcd}	3.81^{bcd}	0.63^{abc}	0.64^{abc}	0.66^{ab}	0.68^{ab}	1.34^{fg}	1.32^{fg}	1.27^{ef}	1.20^{ef}
T_{9}	5.11^{a}	5.18^{a}	5.20^{a}	5.29^{a}	0.76^{ab}	0.77^{ab}	0.79^{ab}	0.81^{ab}	3.58^{a}	3.56^{a}	3.51^{a}	3.44^{ab}
T_{10}	3.53^{bcd}	3.60^{bcd}	3.63^{bcd}	3.71^{bcd}	0.57^{abc}	0.58^{abc}	0.60^{ab}	0.61^{ab}	2.54^{c}	2.52^{c}	2.47^{c}	2.44^{c}
T_{11}	1.68^{bc}	3.75^{bc}	3.78^{bc}	3.88^{bc}	0.66^{abc}	0.67^{abc}	0.69^{ab}	0.70^{ab}	1.46^{f}	1.44^{f}	1.39^{e}	1.36^{e}
T_{12}	5.18^{a}	5.25^{a}	5.28^{a}	5.38^{a}	0.78^{a}	0.79^{a}	0.81^{a}	0.82a	3.65^{a}	3.63^{a}	3.58^{a}	3.55^{a}
T_{13}	3.58^{bcd}	3.65^{bcd}	3.67^{bcd}	3.67^{bcd}	0.59^{abc}	0.60^{abc}	0.70^{ab}	0.79^{ab}	1.15^{ghi}	1.13^{ghi}	1.02^{fgh}	0.86^{fgh}
T_{14}	3.71^{b}	3.78^{b}	3.80^{b}	3.88^{b}	0.68^{abc}	0.69^{abc}	0.71^{ab}	0.73^{ab}	2.18^{e}	2.16^{e}	2.11^{d}	2.04^{d}
T_{15}	5.08^{a}	5.16^{a}	5.18^{a}	5.26^{a}	0.72^{abc}	0.73^{abc}	0.75^{ab}	0.78^{ab}	3.34^{b}	3.30^{b}	3.27^{b}	3.19^{b}
T_{16}	3.61^{bcd}	3.68^{bcd}	3.71^{bcd}	3.79^{bcd}	0.61^{abc}	0.62^{abc}	0.64^{ab}	0.65^{ab}	1.27^{fgh}	1.25^{fgh}	1.20^{efg}	1.17^{efg}
T_{17}	3.74^{b}	3.81^{b}	3.84^{b}	3.91^{b}	0.70^{abc}	0.71^{abc}	0.73^{ab}	0.74^{ab}	2.33^{de}	2.31^{de}	2.26^{cd}	2.23^{cd}
T_{18}	5.14^{a}	5.22^{a}	5.25^{a}	5.35^{a}	0.74^{abc}	0.75^{abc}	0.77^{ab}	0.78^{ab}	3.49^{ab}	3.47^{ab}	3.42^{ab}	3.39^{ab}
T_{19}	3.70^{b}	3.77^{b}	3.81^{b}	3.90^{bc}	0.75^{abc}	0.76^{abc}	0.78^{ab}	0.80^{ab}	1.40^{e}	1.38^{e}	1.33^{d}	1.27^{d}

Mean values within the same row with different superscript lowercase letters are significantly different ($p \leq 0.05$).

Table 3: Impact on antioxidant activity, total flavonoid content and total phenolic content of low-calorie papaya jam with Chia Seed, Stevia, Gum Tragacanth, Grape Juice and Preservative during prolonged storage

Treatments	Antioxidant Activity (%)				Total Flavonoid Content (mg QUE/g)				Total Phenolic Content (mg GAE 100 g−1 dw)			
	0 Day	2 Months	4 Months	6 Months	0 Day	2 Months	4 Months	6 Months	0 Day	2 Months	4 Months	6 Months
T_1	25.19_{f}	23.25_{f}	23.14_{g}	17.03_{f}	39.30_{f}	38.27_{e}	36.54_{f}	29.42_{f}	52.27_{e}	51.10_{e}	49.52_{f}	40.42_{e}
T_2	27.54_{e}	26.59_{e}	25.49_{f}	20.14_{e}	40.45_{e}	39.53_{d}	37.69_{e}	31.57_{e}	53.62_{e}	52.45_{e}	50.87_{f}	43.77_{e}
T_3	26.45_{f}	24.51_{f}	23.40_{g}	19.29_{f}	39.55_{f}	38.60_{e}	36.79_{f}	30.67_{f}	53.43_{e}	51.26_{e}	50.68_{f}	42.58_{e}
T_4	26.30_{f}	25.37_{f}	24.25_{g}	22.14_{f}	39.44_{f}	39.25_{e}	38.68_{f}	37.51f	52.36_{e}	52.19_{e}	49.61_{f}	47.48_{e}
T_5	27.61_{e}	26.68_{e}	25.56_{f}	24.45_{e}	40.51_{e}	40.19_{d}	39.75_{e}	38.58e	54.19_{d}	54.02_{d}	51.44_{e}	49.31_{d}
T_6	26.51_{f}	27.58_{f}	24.46_{g}	$23.35f_{f}$	39.63_{f}	39.41_{e}	38.87_{f}	37.70_{f}	53.54_{e}	52.37_{e}	50.79	48.66_{e}
T_7	27.76_{e}	26.82_{e}	25.71_{f}	20.38_{e}	40.67_{e}	39.65_{d}	38.91_{e}	32.79_{e}	54.26_{d}	53.09_{d}	51.51_{e}	46.41_{d}
T_8	28.58_{cd}	27.64_{cd}	26.53^{cde}	24.42_{cd}	41.65_{d}	40.76_{c}	39.89_{d}	39.72d	55.40_{bc}	54.23_{bc}	52.65_{cd}	48.52_{bc}
T_9	30.44_{ab}	31.50_{ab}	28.39_{ab}	26.28_{a}	43.59_{a}	42.60_{a}	41.83_{a}	41.66_{a}	56.32_{a}	55.15_{a}	53.57_{a}	50.44_{a}
T_{10}	27.88_{e}	26.95_{e}	25.83_{f}	24.72_{e}	40.82_{e}	40.50_{d}	39.05_{e}	38.87_{e}	54.33_{d}	54.16_{d}	51.58_{e}	49.45_{d}
T_{11}	29.73c	28.80_{c}	26.68_{cd}	25.57_{cd}	41.78_{d}	41.16_{c}	40.02_{d}	39.85d	55.49_{bc}	55.32_{bc}	52.74_{bcd}	50.61_{bc}
T_{12}	30.62_{a}	31.69_{a}	28.57_{a}	27.46_{a}	43.70_{a}	43.54_{a}	42.94_{a}	41.78_{a}	56.43_{a}	56.26_{a}	53.68_{a}	52.55_{a}
T_{13}	28.30_{d}	27.36_{d}	26.25_{e}	21.60_{d}	41.45_{d}	40.43_{c}	39.69_{d}	33.23c	55.23_{c}	54.06_{c}	52.48_{d}	47.38_{c}
T_{14}	28.81_{c}	27.87_{c}	26.76_{c}	23.65_{bc}	42.36_{bc}	41.34_{b}	40.60_{bc}	39.43bc	55.57_{bc}	54.4_{bc}	52.82_{bc}	49.69_{bc}
T_{15}	30.31_{ab}	29.37_{ab}	28.26_{ab}	27.15_{a}	42.55_{bc}	41.53_{b}	40.79_{bc}	39.62bc	56.27_{a}	55.10_{a}	53.52_{a}	50.39_{a}
T_{16}	28.43_{cd}	29.50_{cd}	26.38_{de}	24.27_{cd}	41.53_{d}	41.28_{c}	40.77_{d}	39.60d	55.32_{bc}	54.15_{bc}	52.57_{cd}	50.44_{bc}
T_{17}	29.18_{b}	30.25_{b}	28.13_{b}	27.02_{ab}	43.49_{bc}	42.17_{b}	41.73_{bc}	40.56bc	56.22_{a}	56.05_{a}	53.47_{a}	51.35_{a}
T_{18}	30.53_{ab}	31.59_{ab}	28.48_{ab}	28.17_{a}	42.67_{b}	42.48_{b}	41.91_{b}	40.74b	56.37_{a}	56.20_{a}	53.62_{a}	52.48_{a}
T_{19}	28.69_{c}	27.76_{c}	26.64_{cd}	24.53_{cd}	41.22_{c}	40.25_{b}	39.46_{c}	38.30c	54.75_{b}	53.58_{b}	50.99_{b}	48.87_{b}

Mean values within the same row with different superscript lowercase letters are significantly different ($p \leq 0.05$).

The inclusion of stevia and chia seed in low-calorie papaya jam had influenced significantly ($p<0.05$) on crude fibre content (g/100g) throughout treatments and storage (Table 2). The maximum value of crude fiber on day zero was discovered in T_{12} (5.18 g/100g), while minimum showed by T_1 (1.30 g/100g). These values gradually rose to (5.38 g/100g) for T_{12} and (1.38 g/100g) for T_1, respectively during storage. The standard jam initially had an average crude fibre content of (3.70 g/100 g), which increased to (3.90 g/100g) over the course of time.

The incorporation of stevia and chia seed had noteworthy impact ($p<0.05$) on crude fat content (g/100g) of low-calorie papaya jam throughout the treatments as well as storage (Table 2). The highest fat content (0.78 g/100g) was detected in T_{12} while the lowest fat content (0.45 g/100g) was observed in T_1, respectively which subsequently improved to (0.82 g/100g) for T_{12} and (0.60 g/100g) for T_1, respectively during the storage. Initially, standard jam sample had (0.75 g/100g) of crude fat content, which surged (0.80 g/100g) at the end of storage period.

The findings of crude protein content (% dwb) of low-calorie papaya jam are represented in Table 2. The crude protein content of fortified jam is slightly higher than the control sample. Results revealed that maximal crude protein content on day zero was exhibited by the T_{12} (3.65 % dwb), while minimum was observed in T_1 (0.89 % dwb). These values gradually decreased to (3.55 % dwb) for T_{12} and (0.47 % dwb) for T_1, respectively during storage. Crude protein values for the standard sample decreased from (1.40 % dwb) on zero day to (1.27 % dwb) by the end of storage.

Table 3 presents the analysis of antioxidant activity (%) using the DPPH (2,2-diphenylpicrylhydrazyl) radical scavenging method. As expected, the inclusion of stevia and chia seed had a significant positive impact on the antioxidant activity of papaya jam samples. For the fresh samples, T_{12} exhibited the maximum value of an antioxidant activity (30.62 %), while sample T_1 showed the minimum value of an antioxidant activity (25.19 %). Over time, these values gradually dropped to (27.46 %) and (17.03 %) for T_{12} and T_1, respectively. The standard jam initially had an average antioxidant activity of (28.69 %), which decreased to (24.53 %). Compared to the standard, samples containing stevia and chia seed exhibited significant antioxidants due to the higher levels of bioactive components present in these additives.

The inclusion of stevia and chia seed in low-calorie papaya jam had significant ($p<0.05$) impact on total flavonoid content (mg QUE/g) throughout treatments and storage (Table 3). Results revealed that the maximum flavonoid content for the fresh samples on zero day was found in T_{12} (43.70 mg QUE/g), while minimum showed by T_1 (39.30 mg QUE/g). These values subsequently dropped to (41.78 mg QUE/g) for T_{12} and (29.42 mg QUE/g) for T_1, respectively by the end of storage period. The standard jam at day zero had an average total flavonoid content of (41.22 mg QUE/g), which decreased to (38.30 mg QUE/g). Polyphenols, also known as TPC (Total Phenolic Content) (mg GAE 100 g−1 dw), are a class of bioactive substances naturally occurring in plant tissues, especially in fruits and vegetables, as secondary metabolites. The incorporation of stevia and chia seed had noteworthy impact ($p<0.05$) on total phenolic content (mg GAE 100 g−1 dw) of low-calorie papaya jam throughout the treatments as well as storage (Table 3). Initially, on day zero, the maximum total phenolic content observed in T_{12} (56.43 mg GAE 100 g−1 dw) while minimum was found in T_1 (52.27 mg GAE 100 g−1 dw), which gradually decreased to (52.55 and 40.42 mg GAE 100 g−1 dw) for T_{12} and T_1, respectively by the end of storage. Throughout storage, the TPC decreased from (54.75 to 48.87 mg GAE 100 g−1 dw) for standard jam sample (T_{19}).

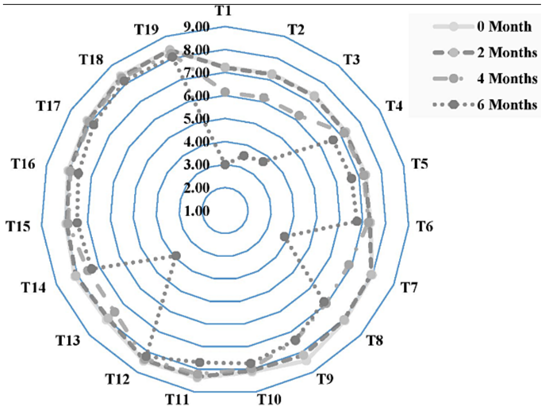

Fig. 2:Organoleptic evaluation (Taste) of low-calorie papaya jam

Organoleptic Evaluation

As expected the incorporation of stevia and chia seed to low-calorie papaya jam influenced significantly ($p<0.05$) on taste scores among the storage time and treatments (Fig. 2). The maximum taste score of freshly prepared jam sample at zero day was noted in T_{12} (8.44), while the minimum taste scores were observed in T1 (7.24), which was subsequently reduced to (8.21) for T_{12} and (6.15) for T_1, respectively, after six months of storage. For the standard treatment (T_{19}), taste scores reduced from 8.29 to 7.95 after six months storage.

Discussion

Foods containing higher level of moisture content tend to have a shorter shelf life.[31] It was observed that the moisture content (%) substantially ($p<0.05$) decreased in all samples over a six-month storage period (Table 1). Depending on the humidity and temperature during storage, the moisture content in jam can either increase or decrease. Additionally, the evaporation of water from the samples over storage may be the cause of the reduction in moisture content. These results correlate with the outcomes of previous researchers who studied the development of low-calorie apple jam with natural sweetener stevia and found a decrease in moisture value when it's being stored for 28 days.[32] Another study also observed similar decline in moisture content of low-calorie apricot jam stored for 60 days.[33]

The water activity (aw) of samples depicted a notable ($p<0.05$) decrease throughout storage (Table 1). The moisture-binding properties of the dietary fibre in chia seeds are responsible for dropping water activity while storage. These findings are compatible with the outcomes of previous authors who noted a reduction in water activity of microalgae-enriched jams with and without added sugar.10Another study also revealed that during storage, cranberry jams with gold flax and chia seeds had a comparable reduction in water activity.[34]

During the storage period of six months, a substantial ($p<0.05$) decrease in ash content of low-calorie papaya jam was observed (Table 1). This decrease in ash content could be attributed to microorganisms utilizing minerals for growth. These outcomes are consistent with those of Chaudhary A, Verma K, and Saharan B. S, who observed a tendency of declining ash content in blueberry jam over time.35

In another study authors investigated the papaya jam for 60 days and revealed that the ash content was decreased with the increase in storage time.[2] Similarly, a decline in ash content values of orange-fleshed sweet potato-pineapple blended jam was seen during storage.[36]

The Table 2 is representing, during storage there was a significant ($p<0.05$) increase in the crude fiber content (g/100g) of low-calorie papaya jam. This increase in crude fibre content during storage might be attributed to the conversion of soluble dietary fiber in the gut and the insoluble polysaccharides that make up the dietary bulk. This trend coincides with the results of previous authors on fortified pineapple jam with chia seeds who observed an increment in crude fibre content during the storage.[37] Another investigation also revealed that the crude fiber content of chia seed-incorporated wheat bread was increased during the storage.[38] Comparably, within 60 days storage, a similar increment in crude fiber content of papaya jam was noticed.[2]

The fat content (g/100g) of low-calorie papaya jam represented a substantial ($p<0.05$) increase over the course of storage (Table 2). Fat forms through esterification reaction between glycerol and fatty acids. This increase in the crude fat content might be associated with the breakdown of double bond in fat, resulting in the decomposition into fatty acids and glycerol. These results are in accordance with the previous investigation performed by researchers who reported that the crude fat content of low calorie papaya jam was increased over the storage of 60 days.[2] The increase in crude fat content was also observed in date bars following a 90-day storage period.[39]

Crude protein (% dwb) levels of treatment sample as well as control significantly ($p<0.05$) decreased as the longer of storage time (Table 2). Protein breakdown into amino acids during storage may lead to a decline in protein content. These results are consistent with previous findings described by Pinandoyo and Masnar, who reported a decreasing trend in protein content of papaya jam during 3 months storage period.[40] Another investigation authors also observed similar decline in protein content of date bars over a period of 90 days in storage.39 Comparably, within three months, protein content dropped down of fortified papaya jam.[41]

The antioxidant activity (%) of low-calorie papaya jam significantly ($p<0.05$) decreased throughout the storage (Table 3). Phenolic compounds are prone to oxidation, leading to a decrease in antioxidants. In the jam-making process, cell structures are disrupted, making phenolic compounds more susceptible to non-enzymatic oxidation and reduction in antioxidant activity may occurs. This decline in antioxidant activity corresponds with the conclusions of Kumar A. L, Madhumathi C, Sadarunnisa S, and Srikanth K who demonstrated a reduction in the antioxidant activity of papaya guava fruit bars during storage.[42] Likewise, a decreasing trend recorded in antioxidant activity of guava jam with added concentrated grape juice during storage and sugar-free sea buckthorn marmalades, respectively.[43, 44]

The total flavonoid content (mg QUE/g) of low-calorie papaya jam was notably ($p<0.05$) decreased throughout six months of storage (Table 3). During storage, the decline in flavonoid levels in fruit products might be linked to the breakdown of antioxidants and their transformation into different metabolites, influenced by fluctuations in temperature, pH, and oxygen levels. These factors affected antioxidant stability and played a significant role in the reduction of flavonoids. These outcomes are in accordance with the findings of Ahmad U, Ahmad R. S, Imran A, Mushtaqq Z, and Hussian S. M, who investigated the Ready-to-serve, low-calorie peach beverage with stevia as a natural sweetener and reported reduction in the total flavonoid content during the storage of 60 days.[45] However, another study also showed the decreasing trend in the flavonoid content of low-sugar berries jam while storage.[46]

The total phenolic content (mg GAE 100 g^{-1} dw) levels in the low-calorie jam samples demonstrated a huge ($p<0.05$) decline over the six months of storage period. The reduction in total phenolic content (TPC) might be due to an increase in acidic concentration resulting from sugar degradation and possibly the hydrolysis of polysaccharides. These findings line up with the previous study performed by researchers who showed a dropping trend in the total phenolic content of guava jam incorporated with concentrated grape juice.[3] In another study authors further demonstrated that the overall phenolic composition of strawberry marmalade with added chia seed were found to fall down in storage.[47] Likewise, Yousefi and Hossein, studied the low-calorie Quince (*Cydonia oblonga*) jam containing stevioside and revealed a drop in total phenolic content during 60 days of storage.[48]

The taste score of low calorie papaya jam illustrated a notable ($p<0.05$) decrease over the six months of storage period. The drop in taste value might be associated with alterations in sugar content, acidity and pH that result from the breakdown of different constituents while storage. These results are consistent with authors who noticed a declining trend in taste of low-calorie jam with natural sweetener stevia during the storage of 28 days.[32] Similar observations of drop in taste scores during the storage of 60 days were observed in of papaya jam.[31]

Conclusion

In summary, this study provides comprehensive details about the implications of chia seeds and stevia on the nutritional composition and organoleptic characteristics of low-calorie papaya jam stored for six months. The findings showed that incorporation of chia seeds and stevia improve the nutritional content (protein, fiber, total phenolic content and antioxidant activity) of low calorie papaya jam. The inclusion of non-caloric sweetener stevia to formulate the low calorie papaya jam also improve the taste without altering its texture. Among the treatments, T_{12} (S3C1P1) (stevia @ 10gm/kg+ chia seeds @ 6.25%/kg + potassium metabisulphite @ 100mg/kg), performed the best in terms of nutritional along with organoleptic characteristics and produced targeted low-calorie papaya jam. Despite the recognition of chia seed for their functional properties, the application of steviol glycosides shows significant promise in processing of fruits, low-calorie foods, and specialized nutritious products, particularly for diabetes patients. Additionally, determining the process improvements and shelf life is essential for practical applications. Storing the jam in refrigerated conditions might help to extend their shelf-life. Furthermore, this study supported the Sustainable Development Goals (SDGs) Zero Hunger and Good Health and Well-being by exploring a healthier sugar alternative along with natural pectin substitutes, examining the stability and nutritional alterations of jam, and promoting healthier low-calorie food choices while maintaining food safety and quality.

Nonetheless, further research is necessary to formulate and introduce a novel product to the consumers.

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The authors do not have any conflict of interest.

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Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Clinical Trial Registration

This research does not involve any clinical trials.

Permission to Reproduce Material from other Sources

Not Applicable.

Author Contributions

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- **Gurpreet Singh:** Writing-review & editing, Validation, Supervision, Formal analysis, Data curation, Project administration, Conceptualization.
- **Rahul R Rodge:** Validation, Methodology, Investigation.
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