Research Article

Effect of Low-Calorie Pumpkin Jams Fortified with Soybean on Diabetic Rats: Study of Chemical and Sensory Properties

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This research investigated the chemical analysis and sensory evaluation of low-calorie formulated pumpkin jams after storage for six months and the effects of the consumption of low-calorie jams on diabetic rats. Pumpkin jam with sucrose, fructose, stevia, and aspartame sweeteners and soybean was prepared and stored at 10°C for six months. Rats were divided into group 1 (negative control), group 2 (positive diabetic groups), and groups 3, 4, and 5 (diabetic groups treated with 10% sucrose, fructose, and stevia soybean jam, respectively). The results indicated that the contents of protein, fat, ash, and fibre were increased in the low-calorie formulated pumpkin jams. The highest sensory scores were recorded for sucrose and fructose soybean jams and then for stevia soybean jam, while the aspartame soybean jam showed significantly lower scores after storage for 3 and 6 months. Rat groups 4 and 5 showed significant decreases in the glucose level, and liver function enzymes activity showed significant increases in insulin and glycogen levels compared to group 2.

Conclusion. Low-calorie pumpkin jams with soybean can be stored for 3 months at 10°C without any change. Stevia pumpkin jam with soybean has antidiabetic effects.

1. Introduction

Jams are produced mainly from fruits and sugar. Sugar (sucrose) derived from sugar cane or sugar beets is added to jams to produce a sweet taste and inhibit microbial growth by binding the water in the jam. However, a high sugar intake is associated with high energy intake, which can increase the risks for diabetes, obesity, and cardiovascular disease. In 2011, the American Diabetes Association recommended monitoring carbohydrate consumption by carbohydrate counting, making better food choices, or experience-based estimation to allow glycaemic control of diabetes, and this has increased the demand for the production of low-calorie foods and thus increased the market share of such foods. Low-calorie jams are produced from low-calorie sweeteners and low-calorie raw materials [1].

Pumpkin (Cucurbita moschata) has a hard skin and is commercially available year-round. The presence of carotenoids in pumpkins gives them their characteristic yellow-orange colour. Pumpkin is eaten as a fresh vegetable or as an ingredient in pies, soups, sweets, marmalades, and jams [2]. Traditionally, pumpkin has been used for treating diabetes. It is very rich in highly bioavailable carotene, and it is low in sugar and lipids, which gives it a low caloric content [3]. Low-calorie sweeteners are added to reduce total calories and maintain palatability. Sweeteners are nutritive and nonnutritive. Fructose is a monosaccharide present in honey and fruit, and when linked with glucose, it forms the natural disaccharide sucrose. Fructose is very sweet and is often made into high-fructose corn syrup for use in soft drinks and processed foods. High-fructose corn syrup (HFCS) is typically 100% glucose, which is produced from corn syrup via enzymatic processing to increase the fructose content and mixing with glucose [4]. Nonnutritive sweeteners are widely used around the world to provide sweetness without or with fewer calories because they are 200 times sweeter than sugar. Aspartame is a methyl ester of aspartic acid and phenylalanine dipeptide. Although aspartame provides 4 kcal/g, it has 180–200 times the sweetness of sucrose. Aspartame breaks down into its components, namely, aspartic acid,
2. Methods

2.1. Materials. A total of 20 kg of pumpkin fruits (Cucurbita pepo L.), soybean powder, and sugar were purchased from a local market in Riyadh, the Kingdom of Saudi Arabia. Citric acid, sodium benzoate, high-fructose corn syrup (HFCS), and polydextrose (food grade) were obtained from El-Gomhouria Co. Stevia (Truvia® steviol glycoside; Bio Nature 24, Görlitz, Germany), streptozotocin (Sigma, St. Louis, MO, USA), and pure aspartame powder (T3A Company, USA) were purchased. BioMerieux kits were purchased from Alkan Co. for Chemicals and Bio-diagnostics. Thirty-five male Sprague Dawley (albino) rats weighing 130–140 g were provided by the Experimental Animals of the Research Centre in Prince Sultan Military Medical City, Riyadh.

2.2. Preparation of Jams. Pumpkin fruits were washed, peeled, and cut into small cubes. Soybean powder was soaked in water for 6 hours. Five jam formulations were prepared to select the best proportion of sweetener, as shown in Table 1.

Pumpkin fruit cubes were boiled. Sieved soybean and polydextrose were then added along with the sucrose, high-fructose corn syrup, aspartame, or stevioside. The mixture was boiled until the desired concentration was reached. Citric acid and sodium benzoate were added, and the mixture was stirred for an additional 1 min. Formulated jams were transferred to sterile jars. The evaluations were conducted immediately after production and after 6 and 12 months of storage at 10°C.

2.3. Proximate Analysis. Protein, fat, ash, fibre, moisture, and carbohydrate contents of the different jam formulations were estimated according to AOAC [7]. The total carbohydrate content was determined by calculating the difference. Total carbohydrate = 100% – (moisture + protein + fat + fibre + ash%). All determinations were done in triplicate.

2.4. Sensory Evaluation. Jam samples (30 g) after 0, 3, and 6 months of storage were randomly served in plastic containers to 15 trained panellists. Responses were recorded using a hedonic scale from 1 to 10 points for different attributes including colour, sweetness, texture, flavour, and overall acceptance according to a previous procedure [8]. All the jam formulations were assessed through sensory evaluation to select the three most acceptable pumpkin jams for biological studies.

2.5. Biological Study. The rats were fed a standard diet prepared according to Reeves et al. [9] for two weeks for acclimation. Food and water were provided ad libitum. Animal management ethical guidelines were followed throughout the study, and permission was obtained from the relevant department. The experiments were carried out with the help of the staff of the Scientific Research Center of the MSD at their experimental animal facility. Seven rats served as the negative control group and were injected with saline only (group 1). Rats in the treatment groups were injected with 70 mg/kg bw of streptozotocin (Sigma, St. Louis, Mo, USA) in the buffer to induce diabetes, which was confirmed by the persistence of hyperglycaemia (above 250 mg/dl) after two days. Diabetic rats were classified into the following groups:

- Group 2: positive diabetic control group fed a standard diet
- Group 3: fed a standard diet with 10% sucrose soybean jam
- Group 4: fed a standard diet with 10% fructose soybean jam
- Group 5: fed a standard diet with 10% stevia soybean jam

The choice of these jam formulations was based on the results of the sensory evaluation study prior to storage. The daily food intake and weekly body weight of the rats were recorded. The feed efficiency ratio (FER) was calculated. After completion of the experimental period (6 weeks), rats were fasted overnight and sacrificed to obtain blood and liver, which were perfused with 50 to 100 mL of ice-cold 0.9% NaCl solution for biochemical analyses.

2.6. Biochemical Analyses. Serum glucose and insulin were estimated after the second, fourth, and sixth weeks. Serum alanine and aspartate aminotransferase (ALT and AST) enzymes activity, liver cholesterol, total lipids, and glycogen were estimated enzymatically according to Henry [10].

2.7. Statistical Analysis. Data were subjected to ANOVA. The means were compared using Duncan’s multiple-range test with a level of significance of 0.05, and this analysis was complemented by the Kruskal–Wallis correlation method to analyse the correlations between parameters at significance levels of 0.05.

3. Results

3.1. Proximate Analysis. The data presented in Table 2 show that the addition of soybean to ordinary jam increases the protein and fat content and decreases the carbohydrate content (as seen in the sucrose soybean jam).
The replacement of sucrose by fructose, aspartame, and stevia as the sweetening agent produced pumpkin jams with generally similar protein and fat contents. The protein contents for most of the low-calorie jam formulations (fructose soybean jam, stevia soybean jam, and aspartame soybean jam) were not significantly different. The fat contents of the samples were within a narrow range (1.11–1.17%). Stevia soybean jam and aspartame soybean jam had higher values of ash, fibre, and moisture and a lower value of carbohydrates compared to fructose soybean jam. The contents of protein, fat, ash, and fibre were higher, and the carbohydrate level was lower in the low-calorie formulated pumpkin jams compared to the ordinary jam. The increase in the moisture content in the stevia soybean jam could be due to the high water-holding capacity of proteins.

The results of the statistical evaluation of the sensory properties of the different jam formulations prepared using different sweeteners are shown in Table 3. The kind of sweetener and presence of soybean protein have a significant influence on the overall acceptability score and have a significant influence on the sensory attributes. The introduction of soybean protein to pumpkin jam with sucrose had an insignificant impact on the colour, sweetness, texture, and overall acceptability but negatively impacted the flavour score. Fructose soybean pumpkin jam tended to have lower scores for texture, flavour, and acceptability, while pumpkin jam with soybean and aspartame had lower scores for sweetness, texture, flavour, and acceptability. Stevia soybean pumpkin jam had lower scores for sweetness, texture, flavour, and overall acceptability. Aspartame soybean pumpkin jam had lower scores for all sensory attributes compared to those of the other jams.

The results of the sensory analysis for the different pumpkin jam formulations after storage for 3 and 6 months are shown in Table 4. The colour was the most appreciated attribute due to the attractive yellow colour of the jam, and the ordinary jam showed a high score for this parameter even after storage for 3 or 6 months. The addition of soybean and sucrose to pumpkin jam resulted in high scores for colour, texture, flavour, sweetness, and overall acceptability and low scores for colour after 3 and 6 months of storage. However, the addition of fructose and soybean to jam resulted in lower scores for colour, texture, and overall sensory qualities after storage for 3 or 6 months, and the flavour score decreased after 6 months of storage. Using nonnutritive sweeteners (stevia and aspartame) with soybean in jam processing could lower the scores of the sensory attributes after storage for 3 and 6 months. The highest scores were recorded for sucrose and fructose soybean jams followed by stevia soybean jam, while the aspartame soybean jam showed significantly lower scores. In the present research, the differences between the sensory evaluation scores prior to storage and after three or six months of storage for ordinary jam and sucrose soybean jam were not significantly different.

As expected (Table 5), body weight gain and feed efficiency ratio were lower in the diabetic groups (2, 3, 4, and 5), and an insignificant difference was observed in the food intake. There was a significant improvement in the body weight and FER after six weeks of consumption of standard diet with jams (groups 3, 4, and 5) compared to the positive control group (group 1), which was only fed a standard diet. Consumption of stevia soybean pumpkin jam had the most desirable impact on the nutritional indicators.

After the injection of streptozotocin, significant hyperglycaemia and lower insulin values were observed at the beginning of the experiment (zero storage time) compared to normal rats (group 1). Positive diabetic control rats (group 2) and rats consuming 10% of the

### Table 1: Ingredients used for preparing the five formulations of pumpkin jams with different sweeteners.

| Formula                  | Pumpkin (g) | Sucrose (g) | HFCS (g) | Aspartame (g) | Stevia (g) | Citric acid (g) | Sodium benzoate (g/kg) | Polydextrose (g) | Soybean soaked (g) |
|--------------------------|-------------|-------------|----------|---------------|------------|----------------|------------------------|-----------------|-------------------|
| Ordinary jam             | 1000        | 1000        | —        | —             | —          | 3.5            | —                      | —               | —                 |
| Sucrose soybean jam      | 950         | 1000        | —        | —             | —          | 3.5            | —                      | —               | 50                |
| Fructose soybean jam     | 950         | —           | 625      | —             | —          | 2.5            | —                      | —               | 50                |
| Aspartame soybean jam    | 950         | —           | —        | 20            | —          | 7              | 0.8                    | 150             | 50                |
| Stevia soybean jam       | 950         | —           | —        | —             | 4          | 7              | 0.8                    | 150             | 50                |

### Table 2: Chemical compositions of the different formulations of pumpkin jam (g/100 g).

| Sample                  | Protein     | Fat         | Ash         | Fibre       | Moisture | Carbohydrate |
|-------------------------|-------------|-------------|-------------|-------------|----------|--------------|
| Ordinary jam            | 3.88 ± 0.33c | 0.04 ± 0.01c | 3.11 ± 0.12cd | 4.66 ± 0.52cd | 20.65 ± 1.11bc | 67.66 ± 7.17a  |
| Sucrose soybean jam     | 19.18 ± 2.41ab | 1.03 ± 0.21b | 4.03 ± 0.28bc | 5.01 ± 0.41c  | 20.71 ± 2.14bc | 50.04 ± 5.07b   |
| Fructose soybean jam    | 20.08 ± 2.46a | 1.11 ± 0.11ab | 5.09 ± 0.15b  | 6.21 ± 0.31b  | 23.31 ± 2.17b  | 44.20 ± 4.11ac  |
| Stevia soybean jam      | 20.11 ± 2.65a | 1.15 ± 0.02a  | 10.69 ± 1.14a | 18.87 ± 1.33a | 33.96 ± 3.80a  | 16.22 ± 1.14d   |
| Aspartame soybean jam   | 20.05 ± 2.63a | 1.17 ± 0.07a  | 10.89 ± 1.12a | 18.81 ± 1.22a | 31.01 ± 3.71a  | 16.07 ± 1.11d   |

Mean ± SD values in the same column with different letters indicate the values differ significantly (p < 0.05).
The nutritional indicators of diabetic rats. Group 1: negative control group; group 2: positive diabetic control group fed a standard diet; group 3: fed a standard diet with 10% sucrose soybean jam; group 4: fed a standard diet with 10% fructose soybean jam; group 5: fed a standard diet with 10% stevia soybean jam; BWG: body weight gain; FI: food intake; FER: feed efficiency ratio. Mean ± SD values in each column with different letters are significantly different (p < 0.05).

## Table 5: Effect of the consumption of different jam formulations on the nutritional indicators of diabetic rats.

| Sample                  | BWG (g)       | FI (g)       |
|-------------------------|---------------|--------------|
| Group 1                 | 75.66 ± 3.22a | 17.88 ± 1.10a |
| Group 2                 | 45.33 ± 2.14c | 16.77 ± 1.3ab |
| Group 3                 | 55.66 ± 2.65cd | 17.55 ± 1.05a |
| Group 4                 | 57.70 ± 2.88c | 18.11 ± 1.11a |
| Group 5                 | 63.77 ± 2.93b | 17.80 ± 1.03a |

Group 1: negative control group; group 2: positive diabetic control group fed a standard diet; group 3: fed a standard diet with 10% sucrose soybean jam; group 4: fed a standard diet with 10% fructose soybean jam; group 5: fed a standard diet with 10% stevia soybean jam; BWG: body weight gain; FI: food intake; FER: feed efficiency ratio. Mean ± SD values in each column with different letters (a, b, c, d) are significantly different at p < 0.05.

### 4. Discussion

These gross composition results as presented in Table 2 are consistent with the published values for soybean composition: high in protein and low in calories, carbohydrates, and fats [11]. Soy protein is used primarily for its functional properties, and it is used in the manufacturing of conventional and convenient foods [12]. In addition, pumpkin boasts many nutritional components; it is rich in proteins, significantly higher levels of insulin compared to the levels of group 2 as illustrated in Table 6.

The most obvious changes in diabetic rats (group 2) were higher values of serum aminotransferase (ALT and AST), liver cholesterol, and total lipids and lower levels of liver glycogen compared to group 1. Diabetic rats consuming different pumpkin jam formulations (groups 3, 4, and 5) showed significantly higher levels of ALT activity and AST activity and liver cholesterol and an insignificant difference in the total liver lipids and glycogen compared to group 1. However, these groups showed significantly lower ALT and AST activities, liver cholesterol, and total liver lipids and significantly higher levels of glycogen compared to group 2, as shown in Table 7.

### Table 6

| Storage (months) | Ordinary jam | Sucrose soybean jam | Fructose soybean jam | Stevia soybean jam | Aspartame soybean jam |
|------------------|--------------|---------------------|----------------------|-------------------|-----------------------|
| 0                | 9.66 ± 0.45a | 9.03 ± 0.40a        | 9.11 ± 0.36a         | 9.21 ± 0.35a      | 7.22 ± 0.23b          |
| 3                | 9.01 ± 0.53a | 8.96 ± 0.54b        | 8.87 ± 0.53b         | 8.63 ± 0.55b      | 5.67 ± 0.22cd         |
| 6                | 8.88 ± 0.44a | 8.66 ± 0.55b        | 8.55 ± 0.85b         | 5.76 ± 0.33c      | 4.77 ± 0.40cd         |

Mean ± SD values in the same column with different letters are significantly different (p < 0.05).
minerals, vitamins, and antioxidants such as carotenoids and tocopherols, but it is low in calories and fat [2].

The sensory attributes of jams (Table 3) depend mainly on the type of fruits and consumer acceptance of their distinctive features. Jam components and their concentrations can cause changes in the gel properties that are reflected in the texture. The yellow colour of pumpkin fruits is one of the most important quality parameters, and it has a significant effect on consumer acceptance of jams [13]. The obtained results are similar to those published by Egbekun et al. [14] and Samaha et al. [15] for pumpkin jam; the pumpkin jam prepared without adding pectin has a yellow colour, an elastic gel texture, and a flat flavour and was well accepted by panellists because pumpkin pulp is rich in pectin and carotenoids. The addition of soybean could diminish flavour and overall acceptance of jams with the different sweeteners. Soybean flour has desirable functional effects including promotion of water binding, emulsification, fat absorption, and gelation [16]. Additionally, the addition of nonnutritive sweeteners (stevia and aspartame) impacts the sweetness and texture of jams. Aspartame decomposes, which reduces its sweetness on heating, so it is used in gelatins, frozen desserts, and cookies and as a substitute for granulated sugar [17]. Polydextrose must be added to low-calorie jams because gel formation specifically requires sugar. The amount of sugar used in jam depends on the amount and quality of the pectin used [13, 18]. Storage time of different pumpkin jam formulations could affect the sensory attributes. As jams are stable and have a relatively long shelf life as a result of their gelled texture and reduced water activity, but during storage, some changes occur in their characteristics, such as colour, aroma, and taste that can impact consumer acceptance [19, 20]. Similar results were also observed in a study conducted by Basu and Shivhare [21] and Kersdap and Nakneen [22] in their evaluation of the sensory characteristics of mango jam. The sensory properties of jams depend mainly on their components, particularly the variety of pumpkin and even on its stage of maturity [13]. However, the ordinary jam had high sensory properties and low fruit content. The sugar in the jams gives them their distinctive sweetness and acts as a preservative. Therefore, low-sugar jams have a higher proportion of fruits and relatively lower caloric values [23].

In view of the nutritive qualities of the formulated soybean jams with different sweeteners (Table 5), soybean (Glycine max) is a valuable source of soy protein, which is an ideal source of the essential amino acids necessary to complement cereal proteins, and it is high in vitamins. Soybean is easy to digest, it has a desirable flavour, and it is low in calories, carbohydrates, and fats; thus, its role in diabetic nutrition is increasing. In addition, soybeans also contain vitamins (B1 and B2), minerals (Fe, Cu, Mn, Ca, Mg, Zn, Co, and K), and minor components such as phenolic compounds, lectin, and protease inhibitors [11, 24]. Pumpkin fruits provide active polysaccharides, essential amino acids, and minerals in addition to carotenoids, ascorbic acid, and provitamin A, which have nutritional benefits and antioxidant activities [25]. The addition of different types of low-calorie sweeteners to jams resulted in nearly the same sweetness levels and had no effect on food consumption. These results are in agreement with those previously reported in [26].

### Table 6: Effect of the consumption of different jam formulations on the glucose and insulin levels of diabetic rats.

| Adaptation | Initially | Glucose (mg/dl) | Insulin (ng/dl) | Second week | Glucose (mg/dl) | Insulin (ng/dl) | Fourth week | Glucose (mg/dl) | Insulin (ng/dl) | Sixth week | Glucose (mg/dl) | Insulin (ng/dl) |
|------------|----------|----------------|----------------|-------------|----------------|----------------|-------------|----------------|----------------|-------------|----------------|----------------|
| Group 1    | 93.41 ± 4.11a | 3.66 ±     | 0.23a          | 93.70 ±     | 3.63 ±     | 95.09 ±     | 3.64 ±     | 97.67 ±     | 3.64 ± 0.35a |
| Group 2    | 92.45 ± 3.96a | 3.59 ±     | 0.22a          | 291.88 ±    | 1.91 ±     | 301.76 ±    | 1.78 ±     | 319.66 ±    | 1.53 ± 0.27d |
| Group 3    | 90.51 ± 3.11a | 3.48 ±     | 0.25a          | 297.61 ±    | 1.85 ±     | 302.60 ±    | 2.05 ±     | 250.70 ±    | 2.25 ± 0.33c |
| Group 4    | 91.33 ± 3.22a | 3.43 ±     | 0.24a          | 295.11 ±    | 1.84 ±     | 300.61 ±    | 2.01 ±     | 199.66 ±    | 2.39 ± 0.42bc|
| Group 5    | 92.49 ± 3.17a | 3.50 ±     | 0.33a          | 294.35 ±    | 1.83 ±     | 305.60 ±    | 2.46 ±     | 125.55 ±    | 2.90 ± 0.54ab |

Group 1: negative control group; group 2: positive diabetic control group fed a standard diet; group 3: fed a standard diet with 10% sucrose soybean jam; group 4: fed a standard diet with 10% fructose soybean jam; group 5: fed a standard diet with 10% stevia soybean jam. Mean ± SD values in each column with different letters (a, b, and c) are significantly different at p < 0.05.

### Table 7: Effect of the consumption of different jam formulations on liver function of diabetic rats.

| ALT (IU/L) | AST (IU/L) | Cholesterol (mg/100 g) | Total lipids (mg/100 g) | Glucogen (mg/100 g) |
|-----------|-----------|------------------------|-------------------------|--------------------|
| Group 1   | 13.25 ± 1.03d | 15.20 ± 1.15d | 3.50 ± 0.13c | 33.67 ± 3.18bc | 6.22 ± 1.66a |
| Group 2   | 27.50 ± 2.99a | 30.65 ± 3.18a | 6.11 ± 1.21a | 41.22 ± 4.35a | 3.85 ± 0.43b |
| Group 3   | 19.35 ± 1.41b | 21.11 ± 2.19bc | 4.11 ± 0.44b | 36.22 ± 3.07b | 5.31 ± 1.15a |
| Group 4   | 18.51 ± 1.33bc | 22.05 ± 3.07b | 4.03 ± 0.34b | 35.71 ± 2.60b | 5.61 ± 1.17a |
| Group 5   | 17.37 ± 1.15c | 19.11 ± 1.22c | 4.18 ± 0.40b | 36.27 ± 2.99b | 5.10 ± 1.14a |

Mean ± SD values in each column with different letters (a, b, and c) are significantly different at p < 0.05.
Results of the consumption of different jam formulations on the glucose and insulin levels of diabetic rats were agreed by Li et al. [27], Fu et al. [28], and Yadav et al. [29] who reported that pumpkin is rich in phenolic compounds, vitamins, flavonoids, and carotenoids, has a low energy, and can reduce blood glucose levels. The active polysaccharides from pumpkin fruits can be developed as new antidiabetic agents due to their ability to increase the levels of serum insulin and improve glucose tolerance. Sugar and fructose are responsible for elevating blood glucose levels, while the nonnutritive sweetener stevia can be safely used within certain limits [30]. Stevioside shows antihyperglycemic and insulinotropic effects in diabetic rats by directly causing pancreatic beta cells to secrete insulin [31]. Soy protein ingestion improves insulin resistance and decreases body fat accumulation in obesity animal models [10]. Data from Abudula et al. [32] and Wiebe et al. [33] support the idea that stevia inhibits ATP-sensitive K-channels that increase glucose-stimulated insulin secretion and decrease blood glucose by suppressing glucagon release in diabetic humans and rodents. STZ inhibits insulin secretion after intravenous administration within seventy-two hours and accumulates in the liver and kidney [34]. Soybean contains phytostrogens like genistein, isoflavones, and daidzein, which are involved in reducing serum cholesterol levels and lowering the lipid content in blood [35, 36]. In addition to having therapeutic properties, pumpkin fruits contain antioxidants (vitamin C, tocopherols, and carotenoids) that significantly increase liver glutathione peroxidase and superoxide dismutase activities, which protect liver cells and cellular components from free radicals by donating electrons and regenerating other antioxidants such as tocopherols [37, 38]. Additionally, the addition of stevioside to jam increases its antioxidant activity, and the resulting jam can inhibit atherosclerosis by improving insulin signalling and lowering the accumulation of lipids due to the lowering of blood cholesterol and decreasing the accumulation of low-density lipoprotein cholesterol [39, 40].

5. Conclusion

This study determined an acceptable formulation for jams made of pumpkin fruit and various low-calorie sweeteners, evaluated their composition (protein, fibre, fat, and minerals), and monitored the effects of six months of storage.

Consumption of low-calorie jams fortified with soybean improves nutritional indicators and serves as a beneficial natural remedy for hyperglycaemia and improving liver function in diabetic rats.

5.1. Recommendation. There have not been enough studies concerning the nutritional value and functional properties of low-calorie jams with different fruits and their shelf life. Further studies are recommended to determine the mechanism of action of low-calorie jams with different low-calorie sweeteners on diabetes in vitro especially on pancreatic and hepatic cells.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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