Hindawi
Journal of Food Quality
Volume 2018, Article ID 9408715, 7 pages
https://doi.org/10.1155/2018/9408715

Research Article

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

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Received 12 August 2018; Revised 8 October 2018; Accepted 24 October 2018; Published 15 November 2018

Academic Editor: Anet Režek Jambrak

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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, phenylalanine, and methanol [5]. Stevia is a botanically derived sweetener from the *Stevia rebaudiana* plant, and it consists of related chemicals called steviol glycosides; stevia only contains the sweetest of these, rebaudioside A. Steviol glycoside is described as having a sweet clean taste [6].

Therefore, the objectives of this study were to determine the chemical and sensory properties of low-calorie formulated pumpkin jams containing soybean and examine the effect of the storage period on the sensory properties of jams. Moreover, the possible effects of the consumption of low-calorie jams on diabetic rats were investigated.

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 bwt 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).

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 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 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 3: Sensory attributes of samples of the 5 different formulations of pumpkin jams in a hedonic test immediately after production (zero storage time).

Sample	Colour 10	Sweetness 10	Texture 10	Flavour 10	Overall acceptability 10	% 100
Ordinary jam	9.66 ± 0.45a	9.57 ± 0.35a	9.13 ± 0.56a	9.70 ± 0.55a	9.50 ± 0.42a	95.12 ± 8.43a
Sucrose soybean jam	9.03 ± 0.40a	9.44 ± 0.43a	9.10 ± 0.53a	8.90 ± 0.41b	8.95 ± 0.30ab	90.84 ± 7.46b
Fructose soybean jam	9.11 ± 0.36a	9.34 ± 0.44a	8.80 ± 0.45b	8.78 ± 0.43bc	8.93 ± 0.33b	89.92 ± 7.35bc
Stevia soybean jam	9.21 ± 0.35a	8.75 ± 0.34b	7.41 ± 0.31c	7.63 ± 0.32d	7.71 ± 0.27c	81.42 ± 6.37c
Aspartame soybean jam	7.22 ± 0.23b	6.20 ± 0.20c	5.78 ± 0.11d	5.81 ± 0.21e	5.11 ± 0.13d	60.24 ± 6.15d

Mean ± SD values in the same column with different letters are significantly different ($p < 0.05$).

Table 4: Effect of storage time on the sensory attributes of different pumpkin jam formulations.

	Storage (months)	Ordinary jam	Sucrose soybean jam	Fructose soybean jam	Stevia soybean jam	Aspartame soybean jam
Colour	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	8.77 ± 0.53b	6.35 ± 0.55c	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
Texture	0	9.13 ± 0.56a	9.10 ± 0.53a	8.80 ± 0.45b	7.41 ± 0.31c	5.78 ± 0.11d
	3	9.03 ± 0.84a	8.96 ± 0.61ab	8.51 ± 0.64b	6.99 ± 0.67c	5.17 ± 0.43d
	6	8.98 ± 0.45a	8.70 ± 0.71ab	8.21 ± 0.76b	6.51 ± 0.44c	4.90 ± 0.49d
Flavour	0	9.70 ± 0.55a	8.90 ± 0.41b	8.78 ± 0.43bc	7.63 ± 0.32d	5.81 ± 0.21e
	3	9.61 ± 0.91a	8.75 ± 0.55ab	8.60 ± 0.83ab	7.13 ± 0.53c	5.40 ± 0.44d
	6	9.58 ± 0.81a	8.67 ± 0.63ab	8.51 ± 0.77b	6.98 ± 0.45c	4.60 ± 0.56d
Sweetness	0	9.57 ± 0.35a	9.44 ± 0.43a	9.34 ± 0.44a	8.75 ± 0.34b	6.20 ± 0.20c
	3	9.38 ± 0.44a	9.21 ± 0.66a	9.10 ± 0.93ab	7.70 ± 0.70c	5.55 ± 0.40d
	6	9.20 ± 0.63a	9.11 ± 0.86a	9.03 ± 0.74ab	6.41 ± 0.43c	4.88 ± 0.53d
Overall acceptability	0	9.50 ± 0.42a	8.95 ± 0.30a	8.93 ± 0.33b	7.71 ± 0.27c	5.11 ± 0.13d
	3	9.41 ± 0.55a	8.94 ± 0.76ab	8.92 ± 0.74ab	7.21 ± 0.44c	5.01 ± 0.42d
	6	9.40 ± 0.55a	8.90 ± 0.70ab	8.93 ± 0.66ab	7.01 ± 0.56c	4.33 ± 0.44d
%	0	95.12 ± 8.43a	90.84 ± 7.46a	89.92 ± 7.35bc	81.42 ± 6.37c	60.24 ± 6.15d
	3	92.88 ± 6.99a	89.70 ± 6.45ab	87.80 ± 8.17bc	70.76 ± 5.9d	53.60 ± 0.41e
	6	92.08 ± 7.11a	88.08 ± 6.77b	86.46 ± 8.11bc	65.34 ± 5.10d	47.08 ± 4.05e

Mean ± SD values in the same row 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.

	BWG (g)	FI (g)	FER
Group 1	75.66 ± 3.22a	17.88 ± 1.10a	0.094 ± 0.004a
Group 2	45.33 ± 2.14e	16.77 ± 1.3ab	0.060 ± 0.001d
Group 3	55.66 ± 2.65cd	17.55 ± 1.05a	0.070 ± 0.002c
Group 4	57.70 ± 2.88c	18.11 ± 1.11a	0.070 ± 0.002c
Group 5	63.77 ± 2.93b	17.80 ± 1.03a	0.079 ± 0.003b

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, and c) are significantly different at $p < 0.05$.

sucrose and fructose soybean jams (groups 3 and 4) had higher levels of glucose and lower levels of insulin after the second, fourth, and sixth weeks compared to group 1. Rats consuming 10% stevia soybean jam (group 5) showed a small improvement in their glucose levels and normal insulin levels after six weeks. Rats consuming 10% low-calorie jam with a nutrient sweetener (fructose) and nonnutrient sweetener (stevia) soybean jam (groups 4 and 5) showed significantly lower levels of glucose and 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.

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,

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

	Adaptation		Initially		Second week		Fourth week		Sixth week	
	Glucose (mg/dl)	Insulin (ng/dl)	Glucose (mg/dl)	Insulin (ng/dl)	Glucose (mg/dl)	Insulin (ng/dl)	Glucose (mg/dl)	Insulin (ng/dl)	Glucose (mg/dl)	Insulin (ng/dl)
Group 1	93.41 ± 4.11a	3.66 ± 0.23a	92.66 ± 5.11b	3.65 ± 0.34a	93.70 ± 4.76d	3.63 ± 0.40a	95.09 ± 5.07e	3.64 ± 0.35a	97.67 ± 6.35e	3.64 ± 0.35a
Group 2	92.45 ± 3.96a	3.59 ± 0.22a	291.88 ± 27.25a	1.91± 0.18b	296.77 ± 31.65a	1.88 ± 0.20d	301.76 ± 35.69a	1.78 ± .19d	319.66 ± 33.99a	1.53 ± 0.27d
Group 3	90.51 ± 3.11a	3.48 ± 0.25a	297.61 ± 26.03a	1.85 ± 0.26b	280.67 ± 29.24ab	1.99 ± 0.21cd	270.60± 30.11ab	2.05 ± 0.23c	240.33 ± 25.70b	2.25 ± 0.33c
Group 4	91.33 ± 3.22a	3.43 ± 0.24a	295.11 ± 28.31a	1.84 ± 0.22b	255.61 ± 28.20b	2.01 ± 0.30bc	240.31 ± 29.66c	2.19 ± 0.26bc	199.66 ± 19.68c	2.39 ± 0.42bc
Group 5	92.49 ± 3.17a	3.50 ± 0.33a	294.35 ± 25.99a	1.83 ± 0.23b	189.66 ± 25.11c	2.46 ± 0.34b	143.60 ± 10.22d	2.85 ± 0.28b	125.55 ± 12.13d	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 $p < 0.05$.

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 Kerdsup and Naknean [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].

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 phytoestrogens 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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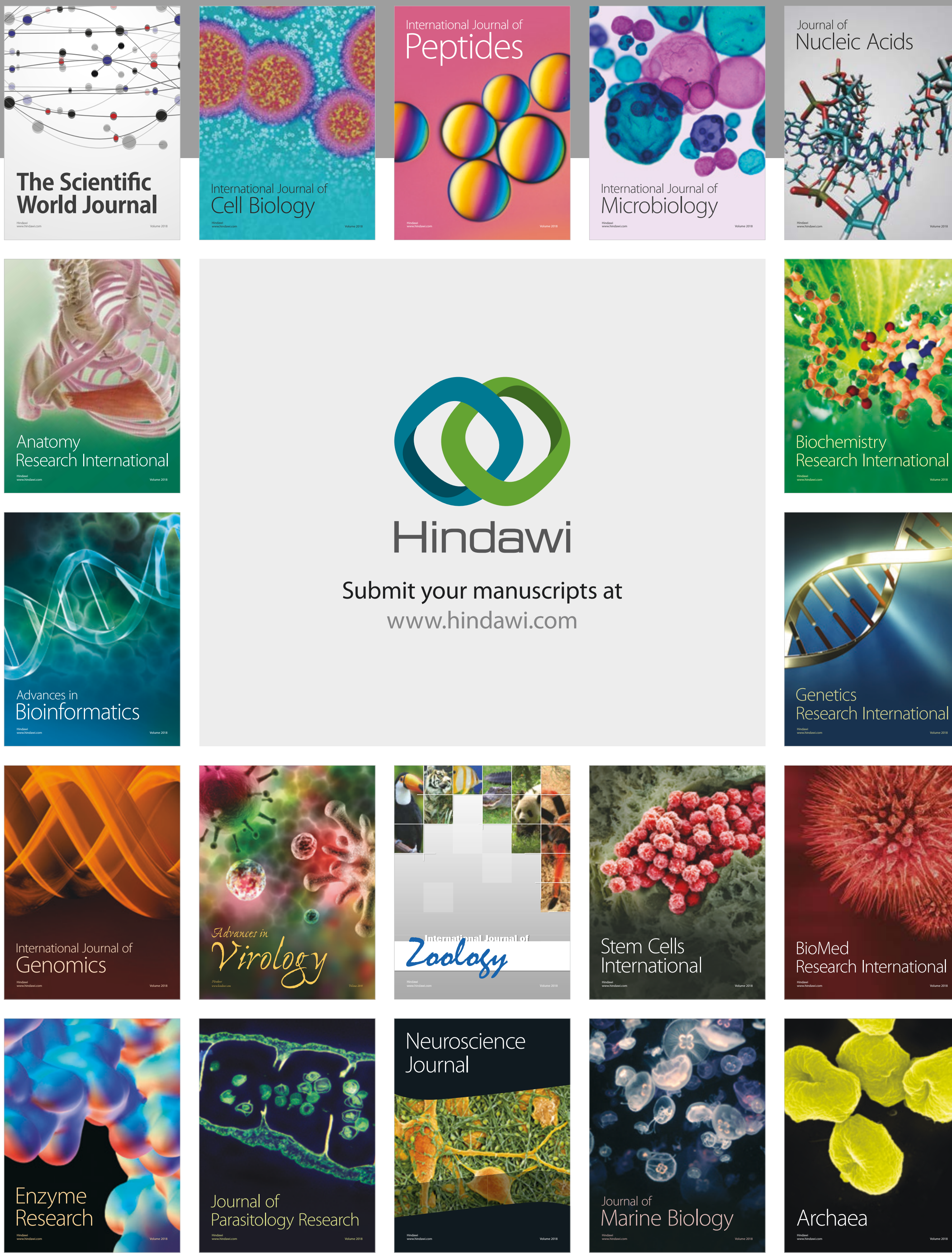
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