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RESEARCH

Development of Low Glycemic Index Pancakes Formulated with Canary Seed (*Phalaris Canariensis*) Flour

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Abstract

Consumers prefer food products that, in addition to nutritional properties, also have effects beneficial to health. Non-conventional food plants such as canary seed (*Phalaris canariensis*) constitute an alternative in the food industry due to nutritional properties, chemical, and bioactive potential. The aim of this research was to develop pancake formulations with the inclusion of canary seed flour to evaluate their proximate composition, overall score, taste and texture sensory acceptability, and glycemic index. Pancakes based on whole-wheat flour mixed with canary seed flour were developed at four substitution levels (control 0, 10, 30, and 50%). The formulations exhibited attractive nutritional properties, mainly due to the levels of protein (~ 8.7%), minerals (~ 5.1%), and total dietary fiber (4.7–5.9%). The overall score and taste showed a statistical difference ($p < 0.05$) between the formulations. The flours with 10 and 30% showed high sensory acceptability with scores of 6.22 and 6.67 respect to 7-point hedonic scale, between the categories "I like it" and "I like it a lot". All formulations presented a low glycemic index (34–39%) that was significantly influenced ($p < 0.05$) as the level of substitution increased. The findings represent a new approach to the use of canary seed in the development of healthy food products.

Keywords Chemical Composition · Dietary fiber · Glycemic Index · Canary seed · Pancakes

Introduction

In recent years, a global trend for all ages has been a strong increase in the consumption of refined, ultra-processed, processed, and ready-to-eat foods such as desserts, bakery, and confectionery products. These foods lack an adequate balance of nutrients and are rich in calories due to their high fat, sugar, and salt content, among others. Its excessive consumption, combined with a sedentary lifestyle, increases the risk of noncommunicable diseases (NCDs) such as diabetes, obesity, and cardiovascular disorders [1]. According to the World Health Organization (WHO), diabetes and kidney diseases were the cause of about 2 million deaths in 2019. Worldwide, 537 million adults suffer from diabetes, and it is estimated that this will increase to 643 million by 2030 [2]. The current situation with such lifestyles is generating health problems among consumers. Changes in dietary patterns and lifestyle are key to preventing and controlling NCDs. Among these modifications in dietary practices that can assist in the prevention and treatment of NCDs is the consumption of foods with a low glycemic index (GI) and rich in bioactive compounds [3].

An alternative in the scientific community is focusing on non-conventional food plants (NCFP), a group of plants that are not normally appreciated by consumers but are considered food since their different botanical parts can be used for human nutrition or consumption. They exhibit good nutritional and bioactive properties after being processed, as well as low or no toxicity [4]. Due to their great potential, their applicability in food products appears to be unlimited, with the bakery industry being one of the many areas that could be approached for the use of these plants [5].

Canary seeds (*Phalaris canariensis* L.) belong to the family *Poaceae*, received the GRAS (Generally Recognized as

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Safe) designation, and were approved for human consumption as a true cereal grain in 2016. Canada produces over 80% of canary seed exports worldwide, with yields ranging between 800 and 1400 pounds per acre, followed by Argentina and Hungary [6]. Compared to other common cereals, such as wheat, oats, barley, and rye, canary seeds have a higher protein content (22%), high content of starch, fiber, proteins with high levels of the amino acids cysteine, tryptophan, and phenylalanine, minerals, and essential fatty acids, such as oleic, linoleic, palmitic, and linolenic acids [7]. It is also a rich source of phenolic and carotenoid compounds associated with antioxidant and antibacterial potential [8]. Magnuson et al. [9] reported that hairless canary seeds can be used for human consumption due to the absence of trichomes, and their consumption has been associated with a lower incidence of hepatic steatosis (which is closely related to metabolic syndromes, especially obesity), insulin resistance, and type 2 diabetes mellitus (DM2). It has also been reported that canary seed biopeptides produced by gastrointestinal digestion in vitro have shown anti-diabetic activity [6].

Consumers now seek and choose healthy but appetizing foods and snacks, indicating that their choices are shifting toward nutritious and sensorial acceptable alternatives. This growing interest in formulating functional and healthy foods has created a recent research trend of implementing new food sources or processing by-products for the development of functional foods with low glycemic index, reduced caloric density [10]. The objective of this study was to develop formulations of traditional breakfast food, such as pancakes, by incorporating canary seed (*Phalaris canariensis*) flour to evaluate its proximate composition and glycemic index.

Materials and Methods

Pancakes Elaboration

The ingredients were purchased in shopping malls located in Merida, Yucatan, Mexico. A base formulation was used, modified to substitute different percentages of wheat flour for canary seed flour. Pancakes were prepared using four levels of canary seed flour incorporation: 0%, 10%, 30%, and 50% (Table 1). These levels were determined through preliminary tests. The formulations were standardized using the following ingredients: Pancake whole-wheat flour (Tres Estrellas®) with 7.8% of protein, 2.9% of fat, and 35.7% of carbohydrates; baking powder (Royal®), vanilla (La Papantla®), cinnamon (Badia®), water (Cristal®), and canary seed powder (Cerepak®) with 9.3% of protein, 1.0% of fat, and 39.8% of carbohydrates. For the preparation, the methodology reported by Martínez-Herrera et al. [11] was used. First, all the ingredients were incorporated, mixed, and whipped by hand until the lumps were completely dissolved. With the resulting mixture, the pancakes were formed using a stainless steel pan to which a little margarine was added. The mixture was gently poured over the pan to cook at a temperature of 50–55 °C, forming a circle of approximately 15 cm. When bubbles formed, the pancakes were gently flipped to cook the other side. The pancakes were then removed from the pan and cooled to room temperature.

Proximate Composition

To characterize the pancakes after pancake cooking, the proximate composition was determined based on the methodologies proposed by the Association of Official Analytical Chemists [12]. Moisture content was determined by weight loss after heating the pancake samples at 100 °C in an oven for a period of 4 h. The ash content was obtained by incineration of the pancake samples in a muffle at 550 °C for a period of 4 h. The crude protein content was determined by the Kjeldahl method, using the 5.71 as the conversion factor of total nitrogen to protein. Crude fiber was calculated after acid and alkaline digestion of the sample with a Fibertec system (Tecator, Sweden). Crude fat content was quantified after extraction with hexane for a period of 4 h in a Soxhlet system (Tecator, Sweden). Total carbohydrates were estimated by difference at 100% as nitrogen-free extract (NFE).

The total dietary fiber (TDF), soluble dietary fiber (SDF), and insoluble dietary fiber (IDF) contents of the pancakes were determined by the enzymatic gravimetric methods proposed by the AOAC [13]. For starch and protein removal, samples were subjected to sequential enzymatic

Table 1 Pancake formulations based on levels of canary seed (*P. Canariensis)*) flour incorporation

Ingredient	Substitution level			
	0%	**10%**	**30%**	**50%**
Pancakes Whole-wheat flour (g)	100 g	90 g	70 g	50 g
Water (mL)	250 mL	250 mL	250 mL	250 mL
Baking powder (g)	8 g	8 g	8 g	8 g
Vanilla (g)	5 g	5 g	5 g	5 g
Cinammon (g)	1 g	1 g	1 g	1 g
Canary seed flour (g)	0 g	10 g	30 g	50

digestion with α-amylase, protease, and amyloglucosidase. In the case of TDF quantification, the enzymatic digestion product was treated with 95% ethanol at 60 °C, to precipitate the soluble fiber before the filtration step. The TDF residue was washed with 78% ethanol and acetone, then dried and weighted. For IDF, the enzymatic digestate was filtered, and the insoluble residue was rinsed with water, dried, and weighted. For SDF, the filtrates and washes were combined and precipitated with 95% ethanol at 60 °C, filtered again, dried, and weighted. Proximal composition and dietary fiber analyses were performed in triplicate for each of the substitution levels.

Sensory Evaluation

The likability rating test was conducted based on the methodology described by Civille and Carr [14]. A panel of untrained panelists was arranged and isolated in test booths where they provided their perceptions in hedonic worksheet. The degree of liking or disliking was established using a 7-point hedonic scale: the top three points indicated liking ("I like it a little", "I like it", and "I like it a lot"), the middle point indicated indifference, and the bottom three points indicated disliking the products ("I dislike it a little", "I dislike it", and "I dislike it a lot"). The attributes evaluated were overall score, taste, and chewing texture. The test was conducted with 80 untrained panelists, to whom three samples with different incorporations of canary seed flour were given. The sensory evaluation was performed in the Sensory Analysis Laboratory of the Facultad de Ingeniería Química of the Universidad Autónoma de Yucatán, Mexico, which is equipped with the following facilities: a food preparation area, a tasting booth equipped with individual compartments area, and an office area; likewise, the material and equipment necessary to serve the samples were available. The samples were provided in plastic containers of equal size, divided and coded with three-digit digits for the three substitutions. The three different pancake formulations were provided in small portion sizes (15 g), as well as bee honey and a glass of water for rinsing between samples. Information regarding the evaluation procedure was explained to the panelists before the test was conducted.

Glycemic Index Evaluation

It was conducted following the method by Granfeldt and Bjorck [15] with the participation of 10 healthy individuals between the ages of 18 and 40. This study was conducted following the guidelines of the Declaration of Helsinki [16], and the participants gave their informed consent to participate. An Optium Exceed glucometer (Abbot) was used to quantify blood glucose levels. In the first test, each of the 10 subjects had a capillary blood sample, which allows quantification of the fasting blood glucose level (t0), taken. Then, each person received a portion of glucose corresponding to 50 g of available carbohydrate (d.b.) that was diluted in 100 mL of water; subjects consumed the total portion offered within 15 min and were only allowed to drink an additional 90 mL of water during the duration of the test. 30 min after ingestion, the second blood sample was taken (t30), and this was repeated at the following times: 45, 60, 90, 120, and 180 min. Subsequently, a second trial was done seven days apart from the first, in which each individual consumed a portion of pancakes (equivalent to 50 g d.b. of carbohydrates). The increase in capillary glucose concentration for the different times was calculated with the glycemic values. A curve of increase in glucose concentration vs. post-ingestion time was constructed, and the area under the curve (AUC) for glucose and the samples under study was evaluated. The glycemic index was calculated as GI = AUC sample/AUC Glucose x 100. The average of the individual glycemic indexes was calculated and reported as the glycemic index for each of the pancakes evaluated.

Statistical Analysis

Data was processed using descriptive statistics. The results from the proximate composition, sensory evaluation, and glycemic index were processed by one-way analysis of variance at a significance level of 5%, according to the methods reported by Montgomery [17]. Duncan's test was applied using the statistical software Statgraphics version 19 to determine the differences between the means of the treatments.

Results and Discussion

Proximate Composition

Table 2 shows the data on the proximate components of the cooked pancakes prepared with the different formulations. The moisture content of all the elaborated products was high (> 50%), with a significant decrease ($p < 0.05$) as the proportion of canary seed flour increased. This could represent a risk to the stability of the products, endangering their preservation due to the amount of water available for the development of microorganisms and undesirable reactions; however, since they are cooked at the time of consumption, this risk is avoidable. Likewise, these water levels are indispensable to provide the texture and palatability desirable in this type of food. All samples presented statistically similar amounts ($p > 0.5$) of mineral residues (5.0-5.2%), which exceeds the maximum value of 3.5% reported for bakery

Table 2 Chemical-proximal composition of pancakes made with different levels of canary seed flour (% w.b.)

Substitution level	Moisture	Ash	Crude fat	Crude protein	Crude fiber	Carbohydrtates (as NFE)
0%	58.11 ± 0.17^{a}	5.12 ± 0.09^{a}	5.98 ± 0.22^{a}	7.96 ± 0.59^{a}	1.15 ± 0.17^{a}	21.68 ± 0.35^{d}
10%	57.73 ± 0.71^{a}	5.02 ± 0.16^{a}	4.88 ± 0.20^{b}	8.75 ± 0.41^{a}	1.07 ± 0.18^{a}	22.55 ± 0.55^{c}
30%	54.59 ± 0.12^{b}	5.16 ± 0.04^{a}	3.99 ± 0.24^{c}	8.78 ± 0.32^{a}	1.32 ± 0.14^{a}	26.16 ± 0.28^{b}
50%	52.57 ± 0.43^{c}	5.22 ± 0.06^{a}	2.90 ± 0.10^{d}	8.74 ± 0.35^{a}	1.43 ± 0.19^{a}	29.14 ± 0.42^{a}

NFE = Nitrogen-free extract. $^{a-c}$ Data with different letters in each column indicates a significant difference ($p < 0.05$); mean of three replicates ± standard deviation

Table 3 Total dietary fiber, soluble fiber, and insoluble fiber content of pancakes made with different levels of canary seed flour (%)

Substitution level	Total dietary fiber	Soluble fiber	Insoluble fiber
0%	6.52 ± 0.16^{a}	1.93 ± 0.11^{a}	4.59 ± 0.23^{a}
10%	5.96 ± 0.14^{a}	$1.79 \pm 0.18^{a,b}$	4.17 ± 0.33^{a}
30%	5.37 ± 0.24^{b}	$1.66 \pm 0.14^{a,b}$	3.71 ± 0.21^{b}
50%	4.78 ± 0.12^{c}	1.39 ± 0.04^{c}	3.39 ± 0.25^{b}

$^{a-c}$ Data with different letters in each column indicate a significant difference ($p < 0.05$); mean of three replicates ± standard deviation

products and derivatives based on conventional cereals such as wheat, maize, oats [18]. On this basis, it could be established that the contribution of minerals in the pancakes made resulted from the incorporation of canary seed flour, making it a good source of phosphorus, potassium, magnesium, and calcium, according to Abdel-Aal et al. [19].

Fat content was significantly ($p < 0.05$) influenced by the amount of canary seed flour added; the higher the amount added, the lower the fat content. Similar behavior was reported by Martínez-Herrera et al. [11], where fat levels decreased as the addition of *Jatropha curcas* flour to the pancake mix increased. This could be due to the low levels of fat in the canary seed flour used in this study. A food is considered unhealthy when its fat content is greater than 7% fat [20]; this value is higher than those obtained in the pancakes with the three different levels of canary seed flour incorporation.

Protein and crude fiber contents showed a similar behavior to that for ashes. In both cases, there was no significant difference ($p > 0.05$) between the pancakes with different levels of canary seed flour incorporated in the formulations. Protein values were at 8%, making it a food with a higher protein content than white bread, whose established limits indicate a maximum protein content of 8% [21], and than traditional pancakes, since they lose moisture during baking, increasing the protein level considerably. A significant increase ($p < 0.05$) in carbohydrate content could also be observed as the proportion of canary seed flour increased. However, since its starch content is low in amylose (17.6% on average) compared to that of wheat (22.7%) or corn (24.5%) [22], nutritional and functional advantages would be expected.

TDF is the one that best explains its behavior in the organism and the benefits of its consumption as a food component. Significant differences ($p < 0.05$) were found between TDF, SDF, and IDF contents in relation to the content of canary seed flour incorporated into the pancake mixes (Table 3). As the degree of substitution increased, a slight decrease in the levels could be observed due to the higher TDF content of wheat flour [19]. The IDF/SDF ratio was 2.38, 2.32, 2.23, and 2.43 for 0, 10, 30, and 50% substitution, respectively. This means that the prepared products have a good balance of these and, therefore, a balance between the physiological and metabolic effects attributed to this functional component. The importance of dietary fiber lies in the relevance it has in preventing and reducing chronic diseases such as colon cancer, diabetes, gastrointestinal cancer, obesity, hypertension, etc. [23]. Therefore, the consumption of the pancakes formulated in this study could provide health benefits to consumers.

Table 4 Average ratings of the likability level of pancakes incorporating canary seed flour

Substitution level	Overall score	Chewing texture	Taste
0%	6.71^{a}	6.65^{a}	6.56^{a}
10%	6.22^{b}	6.56^{a}	6.03^{b}
30%	6.67^{a}	6.58^{a}	6.73^{a}
50%	5.60^{c}	6.38^{b}	5.47^{c}

$^{a-c}$ Data with different letters in each column indicate a significant difference ($p < 0.05$)

Sensory Evaluation

From the results of the study, statistically significant differences ($p < 0.05$) in the overall score between the different levels of canary seed flour inclusion were found. With an average score of 6.71 and 6.67 (Table 4), the panelists preferred the pancake made with control (0%) and 30% canary seed flour, respectively. The pancake with the lowest score (5.6) was made with 50% substitution. All pancakes presented an adequate chewing texture with values between

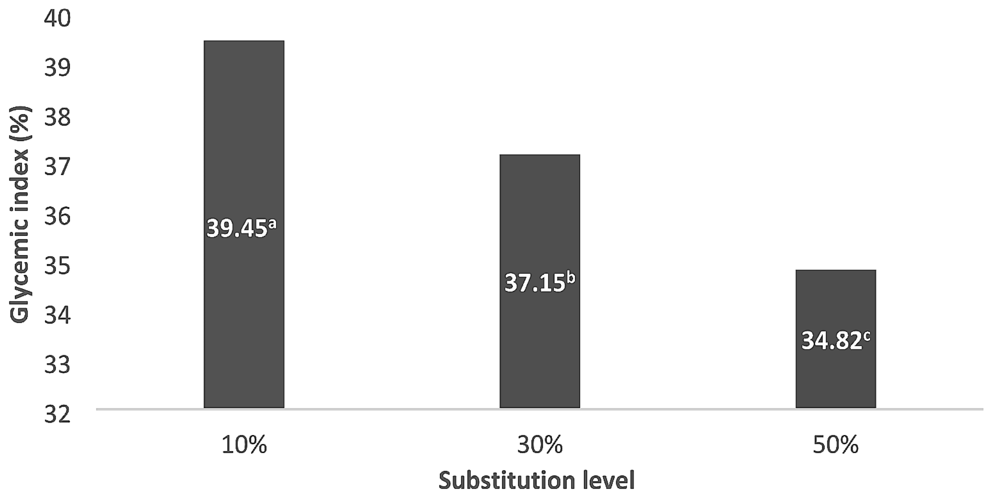

Fig. 1 Glycemic index of pancakes incorporating canary seed flour. [a–c] Data with different letters indicates a significant difference ($p < 0.05$)

6.38 and 6.65. No statistically significant differences ($p > 0.05$) were found for this attribute.

For taste, statistically significant differences ($p < 0.05$) were found between the pancakes evaluated, with high acceptance scores for the control (0%) and those with 30% canary seed flour. The pancakes at 30% substitution met the characteristics of a typical breakfast food sought by consumers, including sweet taste and adequate chewing texture, improving the palatability with the addition of bee honey. In the pancakes with 50% substitution, the panelists indicated a slightly bitter aftertaste from the product, possibly due to them having the highest percentage of canary seed flour, which has a high content of polyphenols and phenolic acids such as ferulic and coumaric acid [19]. The product elaborated with the 10% incorporation had a score of 6.03; however, the panelists felt it was a little insipid, likely due to the predominance of pancake whole-wheat flour in the formulation. Based on the hedonic scale, the pancakes prepared with 0, 10 and 30% canary seed flour in their formulations reached a level of sensory acceptability between "I like it" and "I like it a lot". Similar behavior was found by Sotiles et al. [24], who sensory evaluated cookies made with two different formulations based on canary seed flour and green plantain, mixed in a 1:1 w/w ratio and substituting 6 and 8% of the base flour. Cookies made with both formulations showed high sensory acceptability in color, texture, odor, and flavor, with a predominance of scores in the "I like it a lot" category and with statistical difference ($p < 0.05$) in the perception of the attributes by the tasters.

Glycemic Index of Pancakes Incorporating Canary Seed Flour

Several factors in canary seed flour impact its anti-diabetic properties, such as the content of complex carbohydrates, dietary fiber, and the presence of bioactive compounds such as polyphenols, carotenoids, and biopeptides, among others [25]. Figure 1 shows the glycemic index (GI) response for the pancakes with different levels of canary seed flour inclusion. It can be observed that there were significant differences ($p < 0.05$) and a decrease in value as the amount of canary seed flour in the formulation increased. The low values found could be due to slow digestion of complex carbohydrates and the presence of dietary fiber in the products. In particular, SDF increases the volume of the food bolus, increasing gastric emptying time and IDF acts as a physical barrier to the absorption of compounds such as carbohydrates and lipids responsible for the increase in blood glucose [26]. These components also reduce the action of digestive enzymes, particularly amylases and glucosidases responsible for the release of glucose in the body. Notably, Estrada-Salas et al. [25], found that the biopeptides naturally contained in canary seed showed a 43.5% inhibition of dipeptidyl peptidase IV (DPP IV) enzymes, one of the goals of diabetes treatments. This mechanism could also be the cause of the low GI found in pancakes made with canary seed flour.

According to their glycemic index, foods are classified into three groups: low (GI < 55), medium (56 < GI < 69), and high (GI > 70). Quaker® brand pancakes and waffles have a GI of 67 and 76, respectively, while whole-wheat bread has a GI of 71 [27]. In comparison, pancakes made with canary seed flour had a GI well below 55, which classifies them as low GI foods, while a pancake prepared with a conventional formulation is classified as a medium GI food [27].

Conclusions

Formulations were developed for the preparation of pancakes that satisfactorily incorporated canary seed (*Phalaris canariensis*) flour, with substitution levels of 10, 30, and 50% in relation to pancake whole-wheat flour (0%). The formulations exhibited outstanding chemical characteristics, providing about 8.7% protein, 5.1% minerals, and up to 5.9% total dietary fiber, with an adequate ratio of soluble to insoluble fiber. Flours with 10 and 30% substitution had high sensory acceptability with scores between the "I like it" and "I like it very much" categories. The pancakes made with all formulations were classified as low glycemic index foods, making them suitable for breakfast and for the health care of potential consumers.

Author Contributions All authors contributed to the study conception and design, F. E-F: Experimental work and obtention of results, A. C-R and E. C-P: Material preparation, and data collection and analysis, The first draft of the manuscript was written by L. C-G; D. B-A: project management, conceptualization and validation. All the authors participated in the writing and revision of the article.

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Data Availability Datasets are available from the corresponding author upon request.

Declarations

Ethical Approval Glycemic index procedure was conducted in accordance with the guidelines of the Declaration of Helsinki, 2013 (World Medical Association). All procedures performed were in accordance with the ethical standards of the Autonomous University of Yucatan. This article does not contain any studies with animal subjects.

Conflict of interest The authors declare no conflicts of interest.

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