Biscuits are common snacks, which have a wide variety of flavors. With the enhancement of modern health awareness, regular biscuits with high sugar, oil, fat and low protein cannot meet the demand of customers. Customers need more healthy biscuits in the market. In this study, pumpkin seed meal, konjac along with low-gluten wheat powder were used as the main material and maltitol was added as a sweetener to make a kind of healthy biscuits with high protein, high dietary fiber and low sugar. Pumpkin seed meal is a by-product of the oil production from pumpkin seed, which has high protein content. Pumpkin seed protein is composed of albumin, globulin, glutenin, and proline. It contains high-quality protein and necessary amino acids for people. Konjac is rich in dietary fiber, which can promote intestinal peristalsis. Maltitol is a healthy sugar substitute. Both of them have a low calorie level. In this study, the effects of the addition ratio of the main material (low-gluten wheat powder, pumpkin seed meal, and konjac powder), the addition ratio of plant oil and butter, and the addition amount of maltitol on the flavor and hardness of the biscuits were analyzed by a single-factor test. Besides, the orthogonal test was conducted, and the results showed that the optimal formula was the ratio of the main material (low-gluten wheat powder, pumpkin seed meal, and konjac powder) of 2:1:1, the amount of plant oil and butter of 4 % and 12 %, and maltitol amount of 20 %. According to the nutritional determination, the pumpkin seed meal biscuits contain 20.4 % protein, 18.0 % fat, 1.8 % ash, 59.2 % total carbohydrate (including 19.1 % dietary fiber and 40.1 % available carbohydrate), and 0.6 % water

Keywords: pumpkin seed meal, konjac, maltitol, biscuits, single-factor, orthogonal test

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DEVELOPMENT OF PUMPKIN SEED MEAL BISCUITS

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1. Introduction

Biscuits are one of the popular food products due to their varied taste, attractive appearance, easy availability, and long shelf life [1]. Biscuits were first found in ancient Egypt and they are the main food products in developed countries such as Europe and the United States. They prevail in many countries around the world, and the demand is increasing. According to the different formulas and production processes, they can be divided into crisp biscuits, tough biscuits, soda crackers, sandwich biscuits, wafers, etc. At present, the main representative brands on the market include Oreo, Danone, Carley, Garton and so on. Crisp biscuits and tough biscuits are two major common categories. The characteristic of tough biscuits is their concave flowers, with needle eyes on the surface. The product surface is smooth, its section structure is multilayered, chewing is crunchy and chewy for its unique characteristics. The proportion of sugar and fat in tough biscuits is lower than in crisp biscuits. Generally, sugar content is less than 30 % and oil content is less than 20 %. Crisp biscuits are characterized by their convex flowers, obvious decorative pattern, and compacted structure. The oil content of sweet and loose special products can reach up to 50 %. With the rapid growth of people's income and the continuous improvement of consumption level, the biscuit industry needs to meet a larger consumer group and a broader consumer demand. Biscuits often have high calories as they contain high sugar and oil. Biscuits contain at least 15 % sugar and 20 % fat. The fat content of whole wheat crackers, coarse grain biscuits, soda cookies is even more than 30 %. In addition, biscuits also have a high sodium content. People don't feel salty with a lot of sodium since the sweetness of biscuits hides the salt.

2. Literature review and problem statement

The fat of biscuits, bread, and other processed foods is trans fatty acids. The main source of this fat is the partial hydrogenation of vegetable oil. Too much of these trans fatty acids may cause cardiovascular disease. Besides, the most important ingredients in biscuits are wheat flour, white sugar, cream, and edible essence. Its delicacy will make people eat a lot before they know it. Biscuits with high sugar and oil are bad for people's health. A great deal of starch, fat, and various

additives can cause skin irritation and allergic reactions. Long-term intake of biscuits may lead to skin ruddy deterioration, early appearance of wrinkles, and early aging of the skin.

Some healthy biscuits were developed such as sugar-free biscuits for diabetes patients, more easy digesting biscuits for children, anti-aging and supplement dietary fiber biscuits for elderly people, and high-energy biscuits for sportsmen [2]. An analysis focused on sucrose reduction and its substitution by polyols (erythritol and maltitol) in short dough biscuits was performed [3]. Besides, it has been demonstrated that the addition of high bottle gourd pulp powder benefits consumers [4]. It can improve dietary fiber intake in healthy and diabetic participants and decrease the glycemic index values for snacks. It has been suggested that soluble dietary fiber has the functional property to change the food texture, structure, and viscosity, which might decrease the postprandial glucose levels [5]. Another paper analyzed the potential of wheat flour to improve the nutritional value of biscuits and developed new formulas by adding red corn to make high-quality biscuits. It showed that red corn biscuits can increase the dietary fiber, antioxidants property and other nutrients included in the biscuits, and improve the utilization of indigenous crops grown in Vietnam [6]. Another study explored the physiochemical, sensory, and potential glycemic response properties of biscuits containing barley β-glucan at 6 % w/w, sufficient to meet the EFSA's health requirements related to lowering cholesterol and increasing fecal bulk, and isomaltulose as a sweetener [7]. It is reported that Jerusalem artichoke powder can be a replacement of wheat flour, which can contribute to the fiber content [8]. Besides, many studies were conducted to decrease the digestion properties and more and more biscuits are required to have slow digestion properties [9]. The influence of bioactive compounds including polyphenols on the antioxidant properties of biscuits was determined [10]. Researchers have analyzed the effect of enrichment with proteins and fibers on the nutritive peculiarity of biscuits [11]. It is shown that the incorporation of chickpea flour to biscuits also altered the physicochemical properties and in vitro starch digestibility [12]. Although studies on making healthy biscuits are conducted, however, the types and qualities of such healthy biscuits in the market are still limited. Therefore, research on the development of healthy biscuits to provide customers with new choices is necessary and important. In this study, pumpkin seed meal, maltitol, and konjac were used to make healthy biscuits.

Pumpkin seed meal is a by-product of pumpkin seed during oil extraction. It contains a very high protein content and can provide all the essential amino acids needed for the human body. The biological value of alkali-soluble protein and the ratio of essential amino acids to non-essential amino acid components in the protein are high [13]. At present, there are a few developments and utilization of pumpkin seed meal. It has been reported that pumpkin seed meal can be used to make a strong, elastic, and edible membrane with a certain antioxidant capacity. In terms of nutrition, some scholars have extracted ACE inhibitory peptides, antioxidant peptides, and antimicrobial peptides from the pumpkin seed meal protein. It has been suggested that bioactive peptides in pumpkin seed meal can be supplied as a nutritional reinforcer to functional foods, such as peptide oral solution and solid capsules. Based on the high nutritional value of pumpkin seed meal, this experiment considers it to be one of the main ingredients to make a kind of healthy biscuits.

Maltitol is a new functional sweetener that has attracted wide attention due to its various physiological properties such as low calorie, non-caries, promoting calcium absorption ability. Maltitol is also known as hydrogenated maltose. Its chemical name is 4-O-α-glucopyranosyl-D-sorbitol, the formula $C_{12}H_{24}O_{11}$ [14]. The sweetness of maltitol is 75~90 % sweetness of sucrose. And its heat value was only 5 % of that of sucrose. It has characteristics such as heat resistance, acid resistance, moisturizing and non-fermentation. It doesn't participate in the Maillard reaction. Maltitol is not digested and absorbed human body. It doesn't cause too much rise in blood sugar, thus there is no stimulating effect on the secretion of insulin, which is necessary for glucose metabolism [15]. Maltitol can serve as a sweetener for diabetes and it is an ideal sweetener for children's food products.

Konjac, also known as Konnyaku, is a food produced by the konjac bulb of the taro family plant. Its main component is soluble dietary fiber glucomannan. Konjac can delay the absorption of glucose, and effectively reduce the postprandial blood sugar, thus reducing the burden on the pancreas, so that the sugar metabolism of diabetic patients is in a virtuous cycle [16]. The mucin contained in konjac can reduce the accumulation of cholesterol in the body, prevent arteriosclerosis, cardiovascular and cerebrovascular diseases [17]. Eating konjac can improve the body's immunity, its excellent dietary fiber can stimulate the body to produce a substance that can kill cancer cells, prevent, and control cancer tumors. Besides, cellulose in it can promote gastrointestinal peristalsis, prevent constipation, and reduce the absorption of intestinal fat [17]. It benefits the treatment of intestinal diseases. Konjac is a low heat food. Its water absorption expansion of glutomannan can increase to 30~100 times the original volume, so it can increase satiety and is the ideal food for people on diet. Therefore, it is a benefit to increase the variety of healthy biscuits in the market by the addition of pumpkin seed meal, maltitol, and konjac.

3. The aim and objectives of the study

The aim of the work is to provide a healthy biscuit formula by studying the effects of the addition ratios of low-gluten wheat powder, pumpkin seed meal powder, and konjac powder, the addition amount of plant oil and butter, and the addition amount of maltitol on the biscuits' quality. Compared to normal biscuits, biscuits obtained in this study could provide customers with a healthier choice, which contain low sugar and high dietary fiber.

To achieve the aim, the following objectives were set:

– to determine the effect of adding low-gluten wheat powder, pumpkin seed meal powder, and konjac powder on the sensory evaluation and hardness of biscuits;

– to determine the effect of adding plant oil and butter on the sensory evaluation and hardness of biscuits;

– to determine the effect of adding maltitol on the sensory evaluation and hardness of biscuits;

– to determine the optimal formula of pumpkin seed meal biscuits by orthogonal test;

– to determine the nutritional indicators and GI value of the obtained biscuits.

4. Materials and methods

4. 1. Materials

The materials used in this experiment include low-gluten wheat flour, eggs, whole-fat milk powder, cooking oil, maltitol,

sodium bicarbonate, ammonium bicarbonate, konjac powder, pumpkin seed, which were bought in a local supermarket.

4. 2. Methods

4. 2. 1. Operation process

According to the basic formula of mixed powder (the addition ratio of low-gluten wheat flour, pumpkin seed meal, and konjac flour was set as 2:2:1), 6 % plant oil, 10 % butter, 30 % maltitol, 40 % eggs, 16 % water, 0.5 % sodium bicarbonate and 0.2 % ammonium bicarbonate were prepared. For example, the addition amount of plant oil is 6 % of the weight of the mixed powder. The single-factor experiment is performed according to this basic formula, which means single factor are the variables, and other materials are added according to the basic formula.

First, melt the butter. Then mix the suitable maltitol and water to dissolve the maltitol, and add oil, sodium bicarbonate, ammonium bicarbonate and whole egg liquid. Then mix the mixture. Next, mix the pumpkin seed meal powder, low-gluten wheat powder, and konjac powder. Knead the mixture into dough and rest for five minutes. The dough was required to be evenly organized, moderately soft and hard, slightly flexible, and smooth. Later, remove the dough roll to a thin pancake of 2 mm and place the mold on the pancake, which was on the baking sheet padded with oil paper. Finally, put the loaded cake embryo in an oven that has been preheated to 160 °C for 25 min to make the biscuits appear light brown color, then remove the baked biscuits and cool them down to room temperature naturally.

4. 2. 2. Single-factor experimental design

According to the basic formula, the ratio of low-gluten wheat flour, pumpkin seed meal, and konjac flour was set as 2:2:1, 1.5:2:1.5, 1:2:1, 2:1:1, 1:1:1, respectively, and changes in hardness and organoleptic quality were determined.

The five groups of plant oil were set as 8 %, 6 %, 4 %, 2 % and 0 %, respectively, and the five groups of butter were set as 8 %, 10 %, 12 %, 14 % and 16 %, respectively. Total oil of 16 % was added to make biscuits, and changes in hardness and organoleptic quality were determined.

Maltitol of 15 %, 20 %, 25 %, 30 %, and 35 % was added to make biscuits, and changes in hardness and organoleptic quality were determined.

4. 2. 3. Orthogonal experimental design

Based on the single-factor experiments, the levels of the addition ratio of the main components (low-gluten wheat powder, pumpkin seed meal powder, konjac powder), the addition ratio of plant oil and butter, and the addition amount of maltitol were obtained for the L9 (34) orthogonal test. The test factor and its levels are shown in the table below (Table 1). Changes in hardness and organoleptic quality were determined.

Table 1

Factors and levels of orthogonal test

Levels	Factors		
	The addition of low-gluten wheat powder, pumpkin seed meal powder, konjac powder	The addition of plant oil and butter	The addition of maltitol
1	1:2:1	6 %, 10 %	20 %
2	2:2:1	4 %, 12 %	25 %
3	2:1:1	2 %, 14 %	30 %

The performed factors and levels of the orthogonal test corresponded to the result of the single-factor experimental design. According to this design, the optimized experiments were conducted and optimal conditions were obtained.

5. Results of the effects of three factors with three levels on the biscuits' quality

5. 1. Results of the effect of the addition ratio of low-gluten wheat powder, pumpkin seed meal powder, and konjac powder on the biscuits' quality

Texture profile analysis (TPA), known as «two bite test», can simulate the mouth's chewing action and can give an insight into the samples' behavior. It is a popular method to determine the textural properties of food products by a double compression test [18]. In this study, the hardness parameter was determined by the texture profile analysis. The organoleptic evaluation was used to assess the biscuits' quality (Table 2).

Table 2

Sensory score table

Item	Evaluation standard	Score
Shape	Biscuits have a very complete form, clear decorative pattern, and uniform thickness. No shrinkage, no deformation, no foams, no concave bottom. The fracture surface is layered or porous, without large holes	16~20
	Biscuits have a relatively complete form, relatively clear decorative pattern, and relatively uniform thickness. No shrinkage, no deformation, no big foams, no much concave bottom. The fracture surface is relatively layered, without large holes	8~15
	Biscuits have an incomplete form, no clear decorative pattern, and no uniform thickness. There is contraction and deformation. There are obvious concave bottom sections without layers and with larger holes	0~7
Color	Biscuits have a brown yellow or golden yellow color. The color is basically uniform, and there is no brown or no white color	16~20
	Biscuits have a brown yellow or golden yellow color. The color is basically uniform, and there is no brown or no white color	8~15
	Biscuits have a brown yellow or golden yellow color. The color is basically uniform, and there is no brown and no white color	0~7
Smell	Biscuits have a strong aroma, with a light pumpkin seed fragrance, no unpleasant smell	22~30
	Aromatic flavor is general, with a light pumpkin seed fragrance, no unpleasant smell	8~21
	No aromatic flavor, no pumpkin seed fragrance, have a pleasant smell	0~7
Flavor	Biscuits have suitable sweetness. The taste is crisp and delicate. They are not sticky to teeth. There are no feelings of impurity substances	22~30
	Biscuits have general sweetness. The taste is crisp and delicate. They are not sticky to teeth. There are basically no feelings of impurity substances	8~21
	Biscuits are too sweet or have no sweet taste. The taste is too hard. They are sticky to teeth. There are feelings of impurity substances	0~7

The features are shown in Table 2. Ten trained personnel served as sensory evaluators. According to the sensory score table, the grade of the shape, color, smell, and flavor of each single-factor experiment and orthogonal test were analyzed. The total sensory score of the experiment was 100 points. The score of the shape, color, smell, and flavor is 20, 20, 30, and 30 points, respectively. The higher the total sensory score, the higher the quality of the biscuits obtained by each experiment.

As can be seen from Fig. 1, the three main ingredients (low-gluten wheat flour, pumpkin seed meal powder and konjac powder) have a crucial impact on the biscuits' quality. With the addition ratio of low-gluten flour, pumpkin seed meal powder, and konjac powder of 2:2:1, namely 40 % low-gluten flour, 40 % pumpkin seed meal powder and 20 % konjac powder, the sensory score showed the lowest value among the five experimental levels and hardness showed the highest value among the five experimental levels. At this ratio, the proportion of low-gluten powder and pumpkin seed meal powder was relatively high, the gluten network in the dough was dense and its taste was relatively hard [19].

With the addition ratio of 1.5:2:1.5 and 1:2:1, the sensory scores were increased compared to those of the addition ratio of 2:2:1.

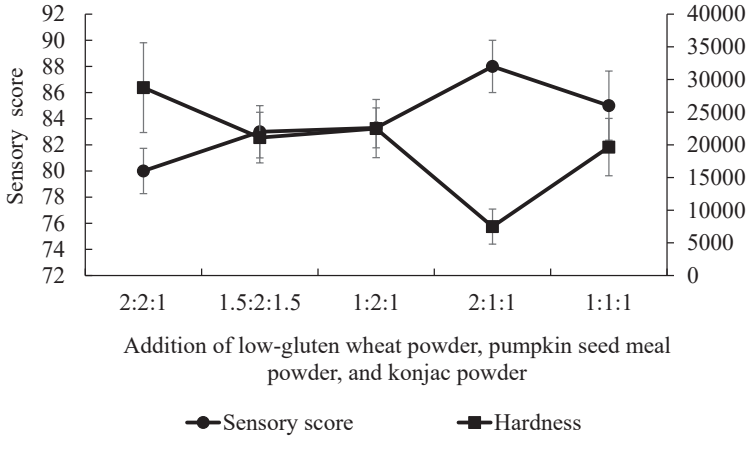

Fig. 1. Effect of the addition ratio of low-gluten wheat powder, pumpkin seed meal powder, and konjac powder on the biscuits' quality

The formula with the addition ratios of 2:2:1, 1.5:2:1.5 and 1:2:1 contained a relatively high content of pumpkin seed meal powder. At the addition ratio of 2:1:1, the sensory score reached the highest level. At this ratio, the hardness of the biscuits was the lowest, the flavor is suitable and harmonious.

With the formula ratio of 1:1:1, namely 33.3 % low-gluten wheat flour, 33.3 % pumpkin seed meal powder, and 33.3 % konjac powder, the sensory score was relatively low. As a result, the addition ratios of low-gluten wheat powder, pumpkin seed meal, and konjac powder of 1:2:1, 2:2:1, and 2:1:1 were selected for orthogonal experiments.

5. 2. Results of the effect of the addition ratio of plant oil and butter on the biscuits' quality

As can be seen from Fig. 2, the total amount of plant oil and butter was 16 %, which was constant for each level. As the amount of plant oil decreased and the amount of butter increased, the sensory score of the biscuits increased when the amount of plant oil decreased from 8 % to 4 %. With the addition amount of plant oil of 4 % and butter of 12 %, the hardness of the biscuits was suitable, the biscuits' crispy taste was improved. They had a loose texture, smooth and bright surface, and the sensory score was much higher.

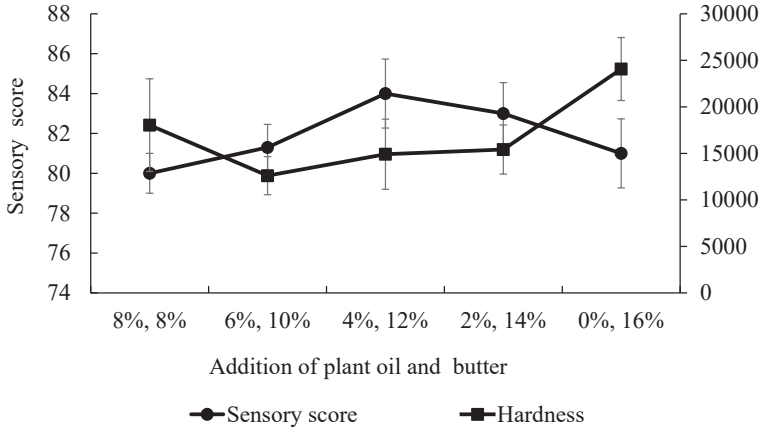

Fig. 2. Effect of the addition ratio of plant oil and butter on the biscuits' quality

When the addition amount of plant oil decreased from 4 % to 0 % and the addition amount of butter increased from 12 % to 16 %, the sensory score was decreased. With the amount of butter higher than 12 %, the taste was relatively greasy. To retain the unique flavor of biscuits containing pumpkin seeds, the plant oil amount of 6 %, 4 %, and 2 % (butter of 10 %, 12 %, and 14 %) was selected for orthogonal experiments.

5. 3. Results of the effect of maltitol addition on the biscuits' quality

As shown in Fig. 3, the sensory score increased when the maltitol addition amount increased from 15 % to 20 %.

When maltitol addition was lower than 20 %, the biscuits had a relatively less sweet taste, thus the taste showed a little bit bitter and the sensory score was relatively low.

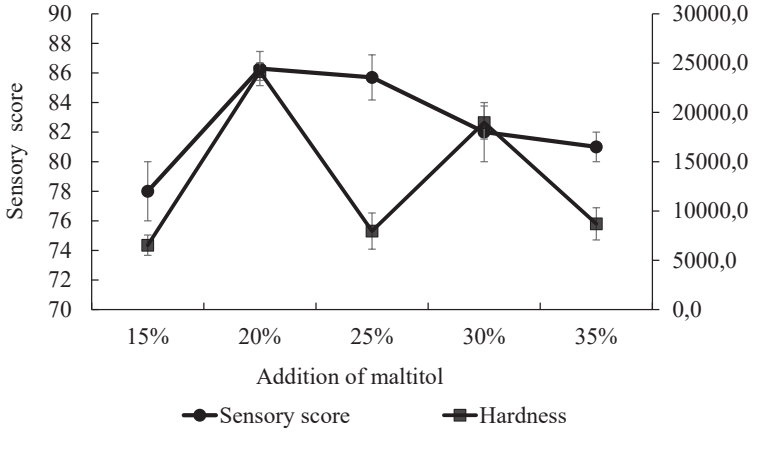

Fig. 3. Effect of the addition amount of maltitol on the biscuits' quality

Furthermore, the maltitol addition would make the dough hard, which can also affect the taste. With the maltitol addition of 20 %, the sweet taste and the bitter taste complemented each other and the sensory score of this group was the highest. With the maltitol amount higher than 20 %, the dough was soft and not easy to shape, the biscuit taste was sweeter and greasier.

5. 4. Results of the orthogonal test

The orthogonal test results are shown in Table 3. The factor priority of each factor on the sensory score of the biscuits was obtained. The results showed that the addition of low-gluten wheat powder, pumpkin seed meal, and konjac powder had more effect than the addition of maltitol on the sensory score of the biscuits, and the addition of maltitol had more effect than that of the addition of plant oil and butter.

Table 3

Results of the orthogonal test

No.	A	Blank	B	C	Mass structure		Sensory score
					The hardness value of biscuits	The fracturability value of biscuits	
1	1	1	1	1	18432.5	12281.8	86.3
2	1	2	2	2	20711.9	12909.6	84
3	1	3	3	3	17691.9	6009.0	87.3
4	2	1	2	3	13358.1	8630.4	84.7
5	2	2	3	1	4925.9	3994.1	85.3
6	2	3	1	2	12733.8	4011.0	84
7	3	1	3	2	25478.8	11853.0	86
8	3	2	1	3	19377.9	8828.7	87
9	3	3	2	1	20956.1	5768.8	88
K1	257.6	257	257.3	259.6	–	–	–
K2	254	256.3	256.7	254	–	–	–
K3	261	259.3	258.6	259	–	–	–
R	7	3	1.9	5.6	–	–	–
Factor priority					A C B		
Optimal combination					A3C1B3		

The optimal formula was A3C1B3. According to the optimal combination, the addition ratio of low-gluten wheat powder, pumpkin seed meal, and konjac powder was 2:1:1. The addition ratio of plant oil and butter was 2 % and 14 %, respectively. The addition amount of maltitol was 20 %. The confirmation experiment of the optimal combination was verified. It showed that the sensory score of the optimal combination was 89.3, which indicated that the result was reliable. Under such conditions, the biscuits have a crispy taste with a light pumpkin seed flavor.

5. 5. Results of the nutritional indicators and GI value of pumpkin seed meal biscuits

The main nutrients of biscuits are carbohydrates, protein, fat, calcium, potassium, iron, and so on. In the present study, the content of protein, fat, ash, total carbohydrate, and water in pumpkin seed meal biscuits was analyzed, as shown in Table 4.

Table 4

Nutritional indicators

Items	Pumpkin seed meal biscuits (g/100 g)	Danisa Butter Cookies (g/100 g)
Protein	20.4	6.2
Fat	18.0	24.3
Ash	1.8	–
Available carbohydrate	40.1	–
Dietary fiber	19.1	–
Total carbohydrate	59.2	66.2
Water	0.6	–

According to the results, the biscuits contained 20.4 % protein, 18.0 % fat, 1.8 % ash, 59.2 % total carbohydrate (including 19.1 % dietary fiber and 40.1 % available carbohydrate), and 0.6 % water. The nutritional information of the famous biscuits of Danisa Butter Cookies is also shown in Table 4. As we can see, the biscuits obtained in this experiment are healthier since they contain higher protein. Besides, according to the GB 28050-2011 National Standard for Food Safety Prepackaged Food Nutrition Labeling General Rules of China, if biscuits have a dietary fiber content higher than 6 g/100 g (solid), they can be called high or rich in dietary fiber. The obtained biscuits contained 19.1 g/100 g dietary fiber, which is much more than 6 g/100 g.

The GI value of food can more accurately reflect the physiological state of human blood glucose fluctuations after food intake, so the GI value can be used as an effective indicator of food causing a human postprandial blood glucose response. A portable glucose meter was used to determine the postprandial blood sugar. The results are shown in Fig. 4.

The postprandial blood glucose curves of intaking 40 g available carbohydrate contained in pumpkin seed meal biscuits and 40 g glucose are shown in Fig. 4.

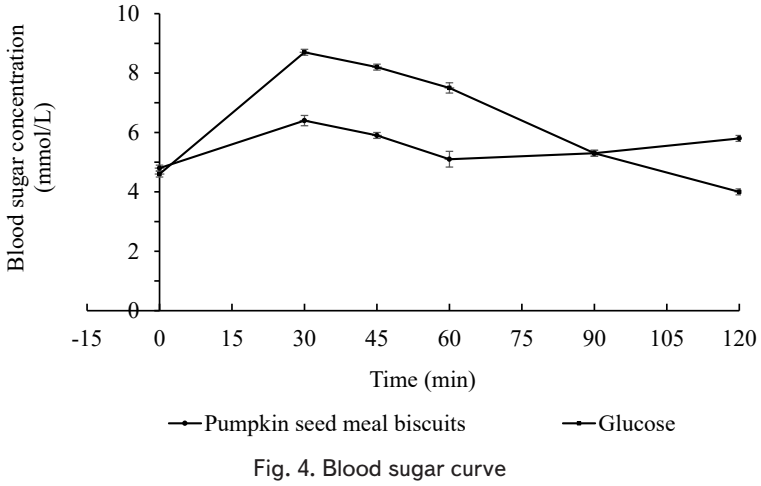

Fig. 4. Blood sugar curve

The curve of intaking glucose was steeper and higher than that of pumpkin seed meal biscuits among the detects before 90 min. After 90 min, the curve of intaking glucose decreased to a lower value than that of pumpkin seed meal. The GI value of the pumpkin seed meal biscuits was calculated as 40.5.

6. Discussion of the results of the single-factor experiment and orthogonal test

In the present study, healthy biscuits with the addition of pumpkin seed meal, maltitol, and konjac powder were obtained. These three factors play a very important role in the biscuits' quality. The main materials ratios of 2:2:1, 1.5:2:1.5, and 1:2:1 had a higher content of pumpkin seed meal than that of 1:1:1 and 2:1:1, which made the physical organization of the biscuits rough (Fig. 1). The obtained product showed a slightly cracked appearance and deep surface color. An appropriate amount of plant oil and butter can not only limit the plasticity of the dough, but also make the dough easy to shape, and achieve the goal of improving the apparent properties of biscuits. Higher butter content (above 12 %) would make biscuits taste greasy (Fig. 2). This was due to the isolation of the oil membranes from each other, so that the gluten particles were not easy to adhere to form the gluten network, resulting in a reduced viscoelasticity of the dough and a poor crack resistance of the biscuits [20]. According to the results, the addition ratios of low-gluten wheat powder, pumpkin seed meal, and konjac powder of 1:2:1, 2:2:1, and 2:1:1, the plant oil amount of 6 %, 4 %, and 2 % (10 %, 12 %, and 14 % butter), the maltitol addition of 20 %, 25 %, and 30 % were selected for the orthogonal test (Fig. 1–3). According to the results of the orthogonal test, the addition ratio of low-gluten wheat powder, pumpkin seed meal, and konjac powder was 2:1:1. The addition ratio of plant oil and butter was 2 % and 14 %, respectively (Table 3). The addition amount of maltitol was 20 %. Under these conditions, the obtained biscuits contained high protein (20.4 %), high fiber (19.1 %) with a low GI value (40.5) (Table 4). Low GI foods refer to foods with a GI value less than 55, and high GI foods refer to foods with a GI value higher than 70. According to the results of the GI value of pumpkin seed meal biscuits of 40.5, it can be concluded that this kind of biscuits is low GI food and promotes the stabilization of postprandial blood glucose. Therefore, the pumpkin seed meal biscuits added with pumpkin seed meal, konjac, and maltitol in this study are healthy and can provide a new type of biscuits in the market. Besides, this study can provide a way of utilization of pumpkin seed meal, which contains high protein but usually wasted. There are also some limitations in this study. Although the biscuits obtained in this study are healthy, their taste cannot reach a very high level compared to the taste of famous biscuits, such as Danisa Butter Cookies. They taste a little bit rough since they contain high dietary fiber of 19.1 %. As a result, when they were produced for the market, the customers are probably limited.

7. Conclusions

1. The sensory evaluation showed an increased value from the material addition ratio of 2:2:1 to 2:1:1 and then showed decreased value from the material addition ratio of 2:1:1 to 1:1:1. The hardness of biscuits showed the lowest value at a ratio of 2:1:1 and the highest value at a ratio of 2:2:1. The addition ratios of low-gluten wheat powder, pumpkin seed meal, and konjac powder of 1:2:1, 2:2:1, and 2:1:1 were selected for the orthogonal experiment.

2. The sensory evaluation showed an increased value from the plant oil addition of 8 % to 4 % and decreased value from plant oil addition value of 4 % to 0 %. The hardness of biscuits showed the lowest value for 6 % plant oil and the highest value for 0 % plant oil. The plant oil amounts of 6 %, 4 %, and 2 % were selected for the orthogonal experiment.

3. The sensory evaluation showed an increased value from maltitol addition of 15 % to 20 %, and decreased value at a maltitol addition value of 35 %. The hardness of biscuits showed the lowest value at a maltitol amount of 15 % and the highest value at a maltitol amount of 20 %. Based on the results of the single-factor experiment, the maltitol amounts of 20 %, 25 %, 30 % were selected for the orthogonal experiment.

4. This study showed that the optimal combination was the ratio of low-gluten wheat powder, pumpkin seed meal, and konjac powder of 2:1:1, the amount of plant oil and butter of 4 % and 12 %, respectively, and maltitol amount of 20 % according to the orthogonal test.

5. According to the results of the nutritional determination of the biscuits, the pumpkin seed meal biscuits contained 20.4 % protein, 18.0 % fat, 1.8 % ash, 59.2 % total carbohydrate and 0.6 % water. The biscuits also contained 19.1 % dietary fiber and 40.1 % available carbohydrate. Their GI value was 40.5. Thus, healthy biscuits containing high protein, high fiber, and low sugar with low GI value were obtained.

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References

1. Hawkins, C., Pattison, D., Davies, M. (2003). Hypochlorite-induced oxidation of amino acids, peptides and proteins. Amino Acids, 25, 259–274. doi: https://doi.org/10.1007/s00726-003-0016-x
2. Jenkins, D. J., Kendall, C. W., Augustin, L. S., Franceschi, S., Hamidi, M., Marchie, A. et. al. (2002). Glycemic index: overview of implications in health and disease. The American Journal of Clinical Nutrition, 76 (1), 266S–273S. doi: https://doi.org/10.1093/ajcn/76.1.266s
3. Laguna, L., Vallons, K. J. R., Jurgens, A., Sanz, T. (2012). Understanding the Effect of Sugar and Sugar Replacement in Short Dough Biscuits. Food and Bioprocess Technology, 6 (11), 3143–3154. doi: https://doi.org/10.1007/s11947-012-0968-5

4. Hussain, A., Kaul, R., Bhat, A. (2018). Development of healthy multigrain biscuits from buckwheat-barley composite flours. Asian Journal of Dairy and Food Research, 37 (02). doi: https://doi.org/10.18805/ajdfr.dr-1328
5. Sharma, S., Rana, S., Katare, C., Pendharkar, T., Prasad, G. B. K. S. (2013). Evaluation of Fiber Enriched Biscuits as a Healthy Snack. International Journal of Scientific and Research Publications, 3 (1). Available at: http://www.ijsrp.org/research-paper-1301/ijsrp-p1377.pdf
6. Srivastava, S. (2012). Preparation and Quality Evaluation of Flour and Biscuit from Sweet Potato. Journal of Food Processing & Technology, 03 (12). doi: https://doi.org/10.4172/2157-7110.1000192
7. Lazaridou, A., Kotsiou, K., Biliaderis, C. G. (2022). Nutritional and technological aspects of barley β-glucan enriched biscuits containing isomaltulose as sucrose replacer. Food Hydrocolloids for Health, 2, 100060. doi: https://doi.org/10.1016/j.fhfh.2022.100060
8. Kārkliņa, D., Gedrovica, I., Reca, M., Kronberga, M. (2012). Production of Biscuits With Higher Nutritional Value. Proceedings of the Latvian Academy of Sciences. Section B. Natural, Exact, and Applied Sciences, 66 (3), 113–116. doi: https://doi.org/10.2478/v10046-012-0005-0
9. Jia, M., Yu, Q., Chen, J., He, Z., Chen, Y., Xie, J. et. al. (2020). Physical quality and in vitro starch digestibility of biscuits as affected by addition of soluble dietary fiber from defatted rice bran. Food Hydrocolloids, 99, 105349. doi: https://doi.org/10.1016/j.foodhyd.2019.105349
10. Hidalgo, A., Ferraretto, A., De Noni, I., Bottani, M., Cattaneo, S., Galli, S., Brandolini, A. (2018). Bioactive compounds and antioxidant properties of pseudocereals-enriched water biscuits and their in vitro digestates. Food Chemistry, 240, 799–807. doi: https://doi.org/10.1016/j.foodchem.2017.08.014
11. Villemejane, C., Denis, S., Marsset-Baglieri, A., Alric, M., Aymard, P., Michon, C. (2016). In vitro digestion of short-dough biscuits enriched in proteins and/or fibres using a multi-compartmental and dynamic system (2): Protein and starch hydrolyses. Food Chemistry, 190, 164–172. doi: https://doi.org/10.1016/j.foodchem.2015.05.050
12. Lu, L., He, C., Liu, B., Wen, Q., Xia, S. (2022). Incorporation of chickpea flour into biscuits improves the physicochemical properties and in vitro starch digestibility. LWT, 159, 113222. doi: https://doi.org/10.1016/j.lwt.2022.113222
13. Bučko, S., Katona, J., Popović, L., Vaštag, Ž., Petrović, L., Vučinić-Vasić, M. (2015). Investigation on solubility, interfacial and emulsifying properties of pumpkin (Cucurbita pepo) seed protein isolate. LWT - Food Science and Technology, 64 (2), 609–615. doi: https://doi.org/10.1016/j.lwt.2015.06.054
14. Ding, S., Peng, B., Li, Y., Yang, J. (2019). Evaluation of specific volume, texture, thermal features, water mobility, and inhibitory effect of staling in wheat bread affected by maltitol. Food Chemistry, 283, 123–130. doi: https://doi.org/10.1016/j.foodchem.2019.01.045
15. Rozzi, N. L. (2007). Sweet facts about Maltitol. Food Prod. Des., 17 (10). Available at: https://talcottlab.tamu.edu/wp-content/uploads/sites/108/2019/01/Maltitol.pdf
16. Shah, B. R., Li, B., Wang, L., Liu, S., Li, Y., Wei, X. et. al. (2015). Health benefits of konjac glucomannan with special focus on diabetes. Bioactive Carbohydrates and Dietary Fibre, 5 (2), 179–187. doi: https://doi.org/10.1016/j.bcdf.2015.03.007
17. Chen, H., Nie, Q., Hu, J., Huang, X., Zhang, K., Pan, S., Nie, S. (2019). Hypoglycemic and Hypolipidemic Effects of Glucomannan Extracted from Konjac on Type 2 Diabetic Rats. Journal of Agricultural and Food Chemistry, 67 (18), 5278–5288. doi: https://doi.org/10.1021/acs.jafc.9b01192
18. Nishinari, K., Kohyama, K., Kumagai, H., Funami, T., Bourne, M. C. (2013). Parameters of Texture Profile Analysis. Food Science and Technology Research, 19 (3), 519–521. doi: https://doi.org/10.3136/fstr.19.519
19. Liu Zhe, Y. Y., Li, S., Meng, Q., Yuan, Z. (2021). Response Surface Design Optimization of Biscuit Formula Using Quinoa Distiller's Grains. Food Research and Development, 42 (17), 129–136.
20. Meng Tingting, L. X., Chao, L., Bailing, Z. (2021). Optimization of potato oatmeal crisp biscuit. Cereals & Oils, 37 (08), 125–128. doi: https://doi.org/10.13982/j.mfst.1673-9078.2021.8.1227