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Study on sensory properties and efficacy evaluation of whole wheat biscuits supplemented with peony seed oil and chia seed

Yongjie MA[1*], Hongliang BAO[2], Xinxin WU[1], Xingyu LI[1], Huijuan YAN[1], Wenbin DONG[3]

Abstract

Nowadays, peony seed oil (PSO) and chia seed (CS) provide a vast potential in the industries of animal feed, food, nutraceutical, pharmaceuticals, and health. In this paper, study on PSO and CS were added into biscuits, and improvement in the nutraceutical properties of biscuits. The studies indicated that biscuits of acceptable overall quality could be prepared using the content of incorporation of PSO (15 g) and CS (12 g) formulations. The total dietary fiber content was positively correlated with different content of PSO and CS. The body weight of the mice in high dose group was lower than that of control group and other groups, indicating that the components PSO and CS in the biscuits could significantly control the body weight of the mice. From the fourth week, average daily food intake of mice in high dose group was significantly lower compared to control group. However, the grasping power of mice in high dose group increased significantly. With the increase in the content of PSO and CS of biscuits, the DPPH radical scavenging activity increased, too. Thus, the results indicated that whole wheat biscuits supplemented with PSO and CS could be considered as dietary fiber-enriched food, and have antioxidant properties.

Keywords: peony seed oil; chia seed; whole wheat biscuits; efficacy evaluation; antioxidant.

Practical Application: This work is expected to deliver practical guidance on adding PSO and CS into biscuits for food production with better functionality and nutrition. The results showed that the intake of a certain amount of PSO and CS could significantly reduce food intake of mice and inhibit weight growth of mice. Therefore, PSO and CS demonstrated a considerable potential to be used not only as fat replacers but also for the development of reduced fat.

1 Introduction

PSO is a new vegetable oil extracted from peony seeds, unique to China (Wang et al., 2021a). The content of unsaturated fatty acids is over 90%, of which the content of α-linolenic acid is around 40%, and of which the content of oleic acid is over 20%. A large number of studies have shown that the unsaturated fatty acids in peony seed oil offer a variety of pharmacological activities, such as anti-oxidation, antibacterial, anti-inflammatory, anti-tumor, enhancing immunity, improving cardiovascular function and so on, which makes PSO have broad application prospect in the fields of medicine and health, health food, cosmetics, and so on (Hammad et al., 2016; Arendt et al., 2015; Song et al., 2019). Based on this, PSO is called "the best oil in the world" by nutritionists because of its special nutritional and health effects. It is the treasure of vegetable oil. PSO has been industrialized and entered public life as a new food resource. Vigorously developing this industry can promote the development of local agriculture and alleviation of poverty in poor farmers (Wang et al., 2021a; Mao et al., 2017). CS is rich in dietary fiber, especially the high content of water-soluble dietary fiber, which can lubricate the intestinal mucosa. For example, it can be added to beverages, cakes, salads, and other foods to improve food flavor (Munoz et al., 2013). CS is also rich in flavonoids and phenols, omega-3 fatty acids, antioxidants, vitamins and minerals, proteins, and so on. It can prevent inflammatory diseases, heart and cardiovascular diseases, diabetes and protect the central nervous system (Jung et al., 2021; Han et al., 2020). It is rich in nutrients that can simultaneously supplement the multiple needs of the body and provide various energies for normal metabolism (Tamargo et al., 2020). As a nutritional supplement, it has good food research and enormous potential for development. The mucus layer produced in contact with water is attached to the colloid, which has a high water absorption capacity (Oliva et al., 2021). After absorption and expansion of water, the volume is several times that of the original, which gives a good sense of satiety. Therefore, it has become a new favorite for fitness and slimming (Tamargo et al., 2020; Oliva et al., 2021).

With the deepening of people's understanding of healthy consumption and whole wheat food, whole wheat biscuits are gaining recognition and attention (Song et al., 2019). At present, whole wheat biscuits in the market often add a large amount of oil and sugar, which has a tremendous negative impact on blood glucose. Such a processing method has offset the advantages of whole wheat raw materials. In addition, the content of wheat flour in many whole wheat biscuits is much higher than that of whole wheat flour, which can not meet the high fiber expected by people. As a new resource food, PSO has a high market price due to its high processing and production cost. Ordinary people are

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[1] *College of Food and Drug, Luoyang Normal University, Luoyang, China*
[2] *Mathematical and Sciences College, Luoyang Normal University, Luoyang, China*
[3] *School of Food and Engineering, Shaanxi University of Science and Technology, Xi›an, China*
*Corresponding author: mayongjie113@163.com

reluctant to buy it and dare not consume it. Although CS has been widely recognized and used abroad, its industrial development in China is still in the preliminary process (Wang et al., 2021b).

To improve the utilization of PSO and CS in food processing and to meet the consumer demand for healthy foods, there was growing interest in the application of dietary fiber and natural antioxidants in baked food products (Pasqualone et al., 2014; Mildner-Szkudlarz et al., 2013). In this study, PSO and CS were added to whole wheat biscuits in different proportions, and their effects on the nutrition, physicochemical properties, and sensory properties of the biscuits were investigated. This work was expected to provide appropriate guidance for the processing of dough food containing PSO and CS. It could be predicted that proper use of PSO and CS in food processing to improve nutritional value and popularity would promote the application scope of PSO and CS, and even solve environmental problems related to direct disposal.

2 Materials and methods

2.1 Reagents and materials

PSO, CS, whole wheat flour, coarse grain flour (rye flour, buckwheat flour, sorghum flour), skimmed milk powder, resistant dextrin, skimmed milk, maltitol, baking powder, baking soda and salt used in the experiment were purchased from Xinxiang Xinliang grain and oil processing Co., China. Fehling reagent, sodium hydroxide, ethanol, potassium sodium tartrate, copper sulfate, hydrochloric acid, acetone, isopropanol, diethyl ether, Phenolphthalein, and so on were bought from Tianjin Fuchen chemical reagent factory. The reagents used in the experiment were all analytical pure. Double distilled water was used throughout. Whole wheat biscuits were referred to as "biscuits".

2.2 Biscuit production

The biscuits recipe consisted of PSO (10 g, 15 g and 20 g), CS (8 g, 12 g and 16 g), whole wheat flour (50 g), coarse grain flour (30 g), skimmed milk (30 g), resistant dextrin (10 g), skimmed milk powder (10 g) and maltitol (15 g). The cooled skimmed milk was added to the weighed PSO and CS powder for emulsification, and the sifted whole wheat flour, coarse grain flour (rye flour, buckwheat flour, sorghum flour), resistant dextrin and skimmed milk powder were added, respectively. Stir with a baking shovel to make a broken dough, then knead it into a uniform and smooth dough. Wrap the prepared dough with fresh-keeping film, let it stand for 15 min, and let the baking powder and baking soda play their role in making the dough slightly expanded and soft. Knead the static dough again, and discharge some tiny bubbles to make it mix more evenly. Lay silicone paper on the top and bottom of the dough and roll it into about 2 mm thin slices, which should be flat, smooth, and consistent in thickness. Press out the figure with a mold and place it in a baking pan covered with silicone paper. They were heated for 16 min in a baking oven, with upper and lower temperatures of 170 °C and 165 °C, respectively. The biscuits were then cooled to room temperature and packaged. For experimental analysis and sensory evaluation, biscuits were crushed to fine powders, stored in a refrigerator at -20 °C and made the same day (Lou et al., 2021).

2.3 Sensory evaluation of biscuits

Ten students in this major were invited to taste the biscuits with different recipes through the quantitative description and sensory analysis. The sensory scores of the products were based on the four criteria of biscuits' appearance, colour, flavor, and texture. Sensory evaluation results were described as x (mean) ± SD (n = 3) and overall quality on a 9-point hedonic scale (Hooda & Jood, 2005; Lou et al., 2021).

2.4 Composition analysis

Total sugar, moisture, fat, protein, acid value, peroxide value, and total carbohydrate were measured according to the standards AACC methods. The total polyphenol was estimated by the Foline-Ciocalteau method (Yang et al., 2010; Lou et al., 2021). Total dietary fiber content in biscuits supplemented with PSO and CS was estimated according to the method described in the literature (Asp et al., 1983; Lou et al., 2021). All analyses were carried out in triplicate. The results were expressed as the mean value, and the standard deviation was calculated.

2.5 Design of animal experiments

Kunming male mice (7-8 weeks old, average bodyweight 20-26 g) were purchased from Xi'an Fourth Military Medical University (Xi'an, China). The mice were randomly divided into three experimental groups and one blank control group according to their body weight. The three experimental groups were referred to as No. 1 (high dose group with PSO and CS added to biscuits), No. 2 (medium dose group with PSO and CS added to biscuits), and No. 3 (low dose group with PSO and CS added to biscuits), with eight mice in each group. The pellet feed was fed for three days to adapt to the environment. The feeding climate and humidity were 18~25 °C and 45~50%, respectively. During this period, the mice drank freely. The experimental group was given gavage with a certain amount of biscuits supplemented with PSO and CS (provided in the form of a prepared solution) every day. Each group was administrated gavage once a day at 4 p.m. The doses of the three experimental groups were ten times the recommended human dose (0.083 g/(kg·d)~0.225 g/(kg·d) body weight/day). The gavage volume was 1 mL/100 g body weight. Biscuits supplemented with PSO and CS was perfused with biscuit solution dissolved in warm water, and the regular blank control group was given the same volume of double distilled water. The mental state, hair, diet, water, and urine of mice were observed every day for seven weeks. Before and after the intervention, the weight and food intake of the mice were recorded every week and the grasping power of the mice was measured. All animals feeding and experimental procedures were guided by the guidelines of the Henan Provincial Experimental Animal Management Committee and approved by the Animal Ethics Committee of Luoyang Normal University.

2.6 Ethics statement

The animal study was reviewed and approved by the Animal Ethics Committee of Luoyang Normal University. Written informed consent was obtained from the owners for the participation of their animals in this study.

2.7 Determination of grasping power

After seven weeks of intervention, the grasping power of mice was measured. A mouse grip tester (Model YLS-13A) developed by the equipment station of the Shandong academy of medical sciences was used. The mouse was placed gently on the grasping board. The tail of the mouse was grasped and pulled back gently. When the mouse grasps the grasping board, pull it back with even force to make the mouse loose. The grasping power of the mouse was recorded, repeated three times, and the maximum value was taken.

2.8 Measurement of antioxidant activity

DPPH is a stable organic free radical, and DPPH radical scavenging ability is one of the classical indexes reflecting antioxidant activity. In this study, 0.5 g of biscuit sample powder was accurately weighed and added to 10 mL of an 80% methanol solution at 25°C. Then, the mixture was placed in the dark for extraction for 24 h. After that, the upper supernatant liquid was obtained by centrifuging the mixture at 10000 r/min and determined the DPPH radical scavenging ability (Wang et al., 2015; Lou et al., 2021). The measurement of antioxidant activity in biscuits supplemented with PSO and CS was estimated according to the method described in the literature (Lou et al., 2021).

2.9 Data processing

Excel 2013 and SPSS 22.0 (SPSS Inc, Chicago, IL, USA) were used for data processing. All analyses were performed in triplicate. Differences among groups were evaluated by one-way ANOVA and $p < 0.05$ was indicated to be a significant difference.

3 Results and discussion

3.1 Influences of different content of PSO and CS on sensory evaluation of biscuits

To ensure that the amount of other raw materials added remained unchanged, the additional standard of PSO was proposed to be 10 g, 15 g, 20 g, and 25 g, respectively. Biscuits were prepared according to the above series of additional standards, and the corresponding sensory scores were completed. The difference in the impact of different addition amounts of PSO on the sensory quality of products could be obtained. The crispness of the biscuits was affected by the addition of PSO. After the PSO was stirred, many tiny pores would be produced to make the biscuits crispy. The sensory score of the biscuits was the highest, crisp and delicious, containing the unique fragrance of PSO when the content of PSO was 15 g. As shown in Figure 1a. When too little PSO was added, the biscuits had a poor taste, no luster, hard texture, and rough surface. With the increase in the amount of PSO, the hardness of the product decreased first, and then increased. With more PSO being added, the sensory score of the biscuits decreased and then increased, but not higher than the highest score. The biscuits tasted too greasy and were easy to break. Therefore, 15 g was selected as the best additional amount of PSO.

To ensure that the additional amount of other raw materials remained unchanged, the additional standard of CS was proposed to be 8 g, 12 g, 16 g, and 20 g, respectively. The toughness and hardness of biscuits could be improved by adding a certain amount of CS which precipitated colloid after soaking in hot water (Brütsch et al., 2019). When the added CS was 12 g, the sensory score was the highest, and the biscuit had a better sense of crispness. When the content of CS was less than 12 g, the sensory score was lower, the gloss was average, the appearance was broken and damaged, and the coagulation was not good. However, when the content of CS was higher than 12 g, the sensory score gradually decreased, and the product was too soft with high toughness and hard texture. As shown in Figure 1b. Therefore, 12 g was selected as the best additional amount of CS. In this study, the whole experimental process was shown in Figure 2.

3.2 Sensory evaluation

A sensory evaluation of biscuits with various PSO and CS content was summarized in Table 1. Appearance and texture were not significant differences between the PSO and CS groups and the control group. Concerning colour, the score differed significantly between the PSO (10 g) and CS (8 g) group and the control group ($p < 0.05$). The values were 7.95 and 8.35, respectively. There was no difference between the scores for the PSO (10 g) and CS (8 g) group or the PSO (15 g) and CS (12 g) group. Above this level, the colour of the biscuits was relatively dark yellow, which was less acceptable. PSO and CS were rich in unsaturated fatty acids and polyphenols, and some components would still undergo an oxidation reaction when contacted with air, which would darken the colour of the

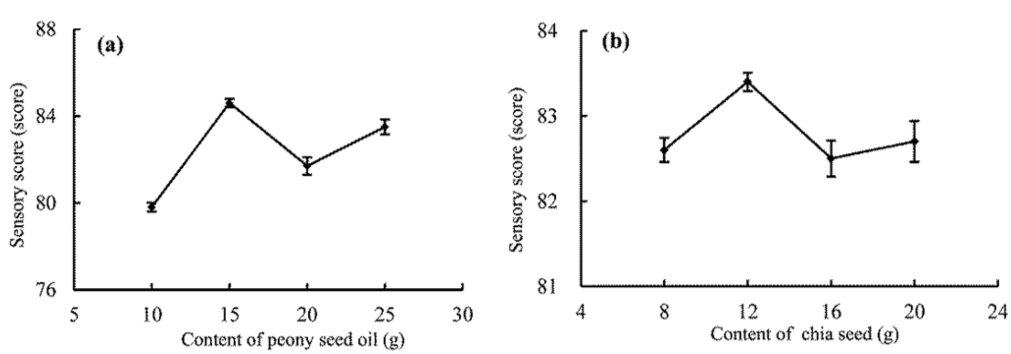

Figure 1. Influences of different PSO and CS additions on sensory evaluation of biscuits: (a) peony seed oil, (b) chia seed.

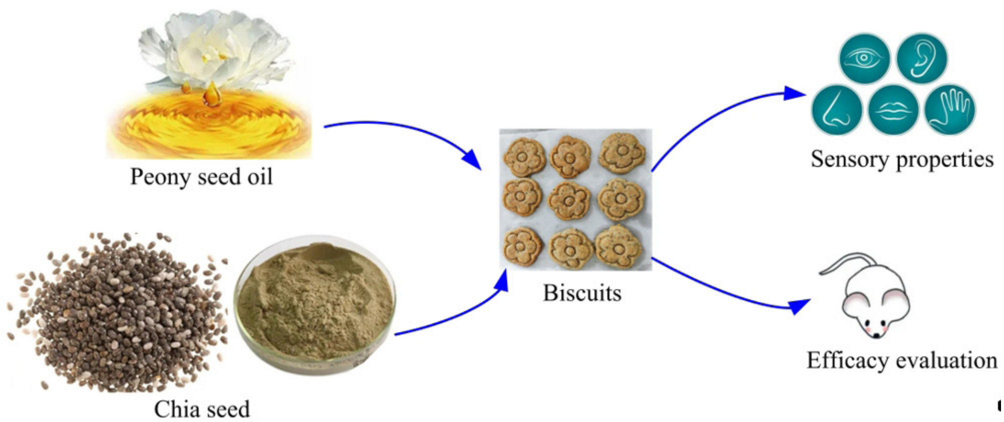

Figure 2. Experimental process diagram

Table 1. Sensory evaluation of biscuits supplemented with PSO and CS.

Content of PSO (g)	Content of CS (g)	Colour (9)	Appearance (9)	Flavor (9)	Texture (9)	Acceptability (9)
0	0	8.35 ± 0.26^{a}	8.51 ± 0.51^{a}	8.26 ± 0.75^{a}	7.96 ± 0.33^{a}	8.47 ± 0.62^{a}
10	8	$7.95 \pm 0.53^{ab*}$	8.22 ± 0.93^{a}	8.17 ± 0.86^{a}	7.63 ± 0.69^{a}	8.21 ± 0.35^{a}
15	12	$7.61 \pm 0.67^{ab*}$	7.89 ± 0.67^{a}	8.31 ± 0.91^{a}	$7.72 \pm 0.55^{a*}$	$8.38 \pm 0.42^{a*}$
20	16	6.82 ± 0.56^{ab}	7.53 ± 0.46^{a}	7.76 ± 0.71^{b}	7.21 ± 0.81^{a}	7.69 ± 0.56^{ab}
25	20	5.10 ± 0.83^{b}	7.36 ± 0.82^{a}	5.87 ± 0.55^{c}	6.79 ± 0.46^{a}	6.81 ± 0.86^{b}

Values are means ± SD of three independent determinations. Means followed by different superscript letters within the same column are significantly ($p < 0.05$) different. *$p < 0.05$ indicates a significant difference between groups.

biscuits. In addition, CS powder was dark brown, and added to the biscuits also decreased the brightness of the biscuits. Compared with the control group, biscuits also became relatively hard with the increase in the level of PSO and CS. The hardness of biscuits might be due to the greater water absorption capacity of the blends resulting in harder biscuits (Ajila et al., 2008). The appearance scores and colour scores showed a similar trend, which could probably be explained by the influence of the latter on the former, to a certain degree. This was consistent with the results of a previous study (Ajila et al., 2008; Lou et al., 2021). The flavor of the biscuits was improved with adding of PSO and CS, and therefore these biscuits had a typical peony fragrance. The score was highest (8.31) when the content of PSO and CS was 15 g and 12 g. Then, the content of PSO and CS increased to decrease the scores. Accordingly, the PSO (15 g) and CS (12 g) groups conferred a sufficient peony fragrance and were favorable to consumers. Concerning texture, increasing the content of PSO and CS resulted in a decreased score, which could probably be a reduced size and elevated surface roughness. Acceptability did not differ substantially from that of the control group when PSO and CS were below 15 g and 12 g, respectively. The biscuits could be accepted by consumers. Overall, considering the attributes of colour, appearance, flavor, and texture, it could be inferred that the content of PSC (15 g) and CS (12 g) was optimum. Thus, biscuits of acceptable overall quality could be made using the content of PSO (15 g) and CS (12 g) formulations. The corresponding biscuits had a regular appearance, relatively smooth surface, and slight peony fragrance.

3.3 Composition analysis of biscuits

The composition of biscuits with different PSO and CS content was shown in Table 2. Moisture, acid value, and peroxide value did not differ significantly between the PSO and CS groups and the control group. The total sugar content in biscuits supplemented with PSO and CS met the national standard (≤5 g/100 g), which belonged to low sugar food. Compared to the control group, PSO and CS groups showed significantly higher ($p < 0.05$) fat, total protein, and total polyphenol contents. When PSO (15 g) and CS (12 g) were used, levels of these three components increased 29.97%, 16.17%, and 43.21%, respectively. The total dietary fiber content was positively correlated with different PSO and CS content. This was attributed to the rich dietary fiber in CS, especially the high content of water-soluble dietary fiber. According to the claim, a foodstuff containing high fiber content might be given only if the product had at least 6 g of fiber per 100 g pointed out by regulation of the European Parliament of the Council (EC) (Lou et al., 2021). Therefore, biscuits supplemented with PSO (≥15 g) and CS (≥12 g) could be considered as a high fiber content food.

3.4 Influence of biscuits on weight gain and food intake in mice

During the experiment, the mice in each group ate usually, grew well, and had no abnormal symptoms such as death, infection and, diarrhea. It could be seen from Figure 3a that the weight of the four groups of mice gradually increased during the experiment. After seven weeks of sample administration,

Table 2. The composition of biscuits with different PSO and CS content.

Component (%)	PSO and CS addition level (g)				
	0	PSO(10), CS(8)	PSO(15), CS(12)	PSO(20), CS(16)	PSO(25), CS(20)
Moisture	2.10 ± 0.48[a]	2.35 ± 0.21[a]	2.74 ± 0.53[ab]	1.98 ± 0.17[ab]	1.86 ± 0.35[b]
Fat	10.01 ± 0.32[d]	11.23 ± 0.11[c]	13.01 ± 0.42[b*]	13.78 ± 0.57[b]	14.62 ± 0.38[a]
Total protein	7.11 ± 0.26[d]	7.94 ± 0.57[d]	8.26 ± 0.23[c*]	8.87 ± 0.47[b]	9.32 ± 0.19[a]
Total carbohydrate	62.81 ± 3.16[a]	63.37 ± 4.65[a]	58.19 ± 2.87[ab]	54.87 ± 4.12[ab]	51.38 ± 4.15[c]
Total sugar	2.16 ± 0.03[f]	2.81 ± 0.17[e]	3.61 ± 0.12[d*]	3.21 ± 0.27[a]	3.37 ± 0.19[a]
Acid value	0.187 ± 0.12[ab]	0.192 ± 0.17[a]	0.195 ± 0.11[b]	1.01 ± 0.26[ab]	0.197 ± 0.14[b]
Peroxide value	0.05 ± 1.17[c]	0.07 ± 0.134[f]	0.06 ± 0.18[d]	0.07 ± 1.28[c]	0.06 ± 0.13[a]
Total dietary fiber	1.23 ± 0.15[c]	6.37 ± 0.11[e]	9.21 ± 0.17[f]	10.89 ± 0.35[c]	12.36 ± 0.41[a]
Total polyphenols	0.81 ± 0.12[c]	0.97 ± 0.25[c]	1.16 ± 0.19[b*]	1.27 ± 0.03[b]	1.31 ± 0.14[a]

Values are means ± SD of three independent determinations. Means followed by different superscript letters within a row are significantly ($p < 0.05$) different. *p < 0.05 indicates a significant difference between groups.

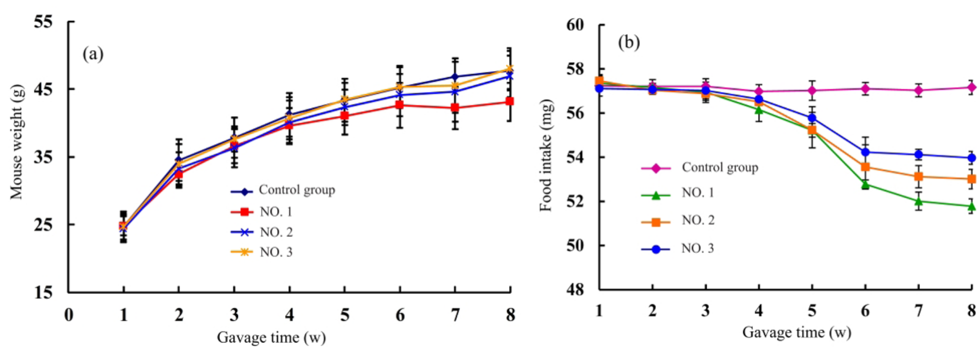

Figure 3. Influences of biscuits on weight gain and food intake in mice: (a) weight gain (g), (b) food intake (mg).

the weight of the four groups of mice increased compared with 0 weeks. The high dose group (No. 1) was significantly lower than the control group and other groups, which might be due to the unique viscous properties of PSO and CS components in the biscuits, which made the mice feel full. Compared with the control group, the body weight of the mice in the high dose group increased the most slowly from the beginning of sample administration to the first week, indicating that PSO and CS components in the biscuits could significantly control the body weight of the mice in the growth period. From the fourth week, the average daily food intake of the mice in the high dose group (No. 1) was evidently lower than that in the control group. In contrast, the food intake of mice in the low dose group (No. 3) and the medium dose group (No. 2) was not evidently different from that in the control group. As shown in Figure 3b. This conclusion was consistent with Figure 3a. The nutrition intervention of high protein and high dietary fiber food should be applied to people who lose weight and control body weight, which could effectively reduce body weight. This might be related to the high-quality proteins such as whey protein changing the metabolic mode of lipid molecules and promoting lipolysis (Bowen et al., 2018). In addition, dietary fiber formed substances with high viscosity through the action of gastrointestinal tract to improve the density of contents. The included glue base could reduce the gastric emptying rate, delay and reduce the absorption of cholesterol, bile acid, glucose, and other substances (Ren et al., 2017). Therefore, it was found that dietary fiber could effectively inhibit weight gain in mice. The results showed that the intake of a certain amount of PSO and CS could significantly reduce the food intake of mice and inhibit the weight growth of mice.

3.5 Influence of biscuits on the grasping power of mice

Skeletal muscle is the muscle attached to the bone, accounting for 35~40% of body weight. It plays an important role in providing power to the body, protecting organs, promoting blood circulation, maintaining posture, and generating heat. Unreasonable weight control will increase the decomposition of skeletal muscle, lead to loss of skeletal muscle, reduce the proportion of muscle content to body weight, and decrease the strength of skeletal muscle, which will seriously affect human health and quality of life (Coker et al., 2019). After clarifying the effects of biscuits supplemented with PSO and CS on weight control and fat content reduction, this study further examined the influences of biscuits on the grasping power of mice. After seven weeks of intervention, the grasping power of the mice increased in a dose-dependent manner. The grasping power of mice in the high dose group increased significantly compared with the control group, and there was no significant difference between the middle dose group and the low dose group, and the control group. As shown in Figure 4.

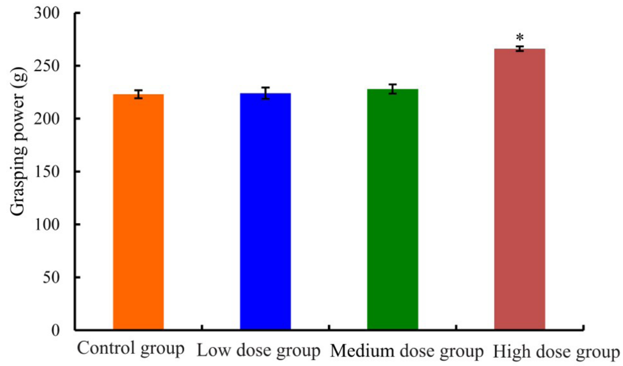

Figure 4. Influences of biscuits on the grasping power of mice. *P < 0.05 indicates a significant difference between groups.

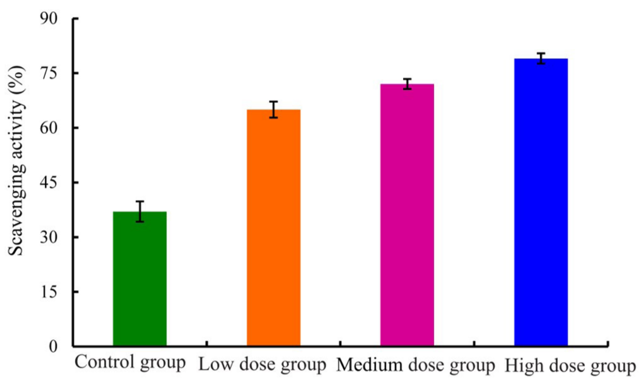

Figure 5. DPPH radical scavenging activity of biscuits with different PSO and CS content.

3.6 Antioxidant properties of biscuits

The antioxidant properties of the biscuits were determined by the method of DPPH. The experimental results were shown in Figure 5. Compared with the control group, the DPPH radical scavenging activity was evidently higher. DPPH radical scavenging activity increased when the content of PSO and CS increased. The increase in the free radical scavenging might be due to an increase in the content of polyphenols and carotenoids through the incorporation of PSO and CS (Ajila et al., 2008; Munoz et al., 2013; Chen et al., 2022). In addition, the observed increases with increasing PSO and CS content suggested the excellent antioxidant effect of PSO and CS in vitro (Santa Cruz Olivos et al., 2021; Lou et al., 2021). Accordingly, adding PSO and CS to biscuits could improve antioxidant performance and dietary fiber content, thereby increasing health benefits. PSO and CS could be a promising natural antioxidant, which might enhance the shelf life and quality of biscuit products.

4 Conclusions

The ingredients of biscuits supplemented with PSO and CS showed that it was a good source of phytochemicals such as protein, dietary fiber, and total polyphenols. Acceptable overall quality biscuits could be prepared using the content of incorporation of PSO (15 g) and CS (12 g) formulations. The corresponding biscuits had a regular appearance, relatively smooth surface, and a slight peony fragrance. The studies showed that the total dietary fiber content was positively correlated with different PSO and CS content. Compared with the control group and other groups, the body weight of the mice in the high dose group was significantly lower. This indicated that PSO and CS components in the biscuits could significantly control the body weight of the mice in the growth period. From the fourth week, the average daily food intake of mice in the high dose group (No. 1) was evidently lower than that in the control group. However, the grasping power of mice in the high dose group increased obviously compared with the control group. An antioxidant activity test indicated that the content of incorporation of PSO and CS could significantly improve the antioxidant activity of biscuits. The PSO and CS addition had a minor influence on digestibility but significantly increased dietary fiber and polyphenol contents of the biscuits. The content of PSO and CS in the biscuits was higher than 15 g and CS 12 g, respectively, which met the needs of modern "high dietary fiber" healthy food. Thus, as a new resource material, PSO and CS could be used to prepare biscuits and other foods with better functionality and nutrition. These results provide a basis for their effective utilization in the food industry.

Conflict of interest

The authors declare that they have no conflicts of interest.

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