Available Online: 17 December 2025 DOI: 10.54254/3029-0821/2025.30741

Process optimization for lotus-root total dietary fiber cookies based on physicochemical properties

Haiying Liao[1], Zituo He[1], Guican Liang[1], Shengchang Li[1], Yiming Sun[1*]

[1]Guangxi University of Chinese Medicine, Nanning, China

*Corresponding Author. Email: 290957109@qq.com

Abstract. This study aims to increase the total dietary fiber content in cookies, reduce excessive sweetness in baked products, and enhance satiety, thereby providing a reference for developing a low-fat, high-fiber cookie. Using water-holding capacity, expansion ratio, and sensory evaluation as indicators, we optimized four factors—total dietary fiber particle size, total dietary fiber addition level, butter amount, and powdered sugar amount—through single-factor experiments and an orthogonal design. The optimal formulation obtained was as follows: dietary fiber passing through a 160-mesh sieve; dietary fiber addition level of 11%; 35 g of powdered sugar; and 25 g of butter. Cookies produced under these conditions had a uniform and regular appearance, an appealing golden color, and a crisp yet appropriately firm texture, accompanied by a rich, sweet aroma.

Keywords: total dietary fiber, lotus root, cookies, process optimization, orthogonal design

1. Introduction

Lotus root (Nelumbo nucifera G.) is mildly sweet and crisp, rich in nutrients and bioactive components. It has the functions of clearing heat and cooling the blood, stopping bleeding, and replenishing blood, and is considered both a food and a medicinal material [1,2]. During processing, most lotus-root nodes are discarded despite being edible [3]. Fresh lotus root and its nodes contain a substantial amount of total dietary fiber, accounting for 66.34% [4]. Dietary fiber, known as the "seventh nutrient," not only improves gut health but also helps prevent cardiovascular and cerebrovascular diseases and regulates blood glucose and lipid levels [5–7]. Using acid–alkali treatment, enzymatic methods, or biological fermentation, the extraction yield of total dietary fiber from lotus root and its discarded nodes can reach 59.23% [8].

In recent years, research on new cookie products has increasingly focused on functionality and nutrition. Dietary fiber can reduce the cloying sweetness often associated with baked goods, enhance satiety, lower the absorption of fats and calories, and mitigate postprandial blood glucose spikes [9,10]. Properly incorporating dietary fiber into cookies can improve nutritional value, enhance gluten hydration, and extend shelf life [11]. Current lotus-root-based commercial products include lotus-root juice beverages, dietary-fiber lotus-root powder, salted lotus root, and canned lotus root [12]; cookies enriched with dietary fiber, such as quinoa fiber cookies, have also been developed [13].

This study uses the total dietary fiber extracted from lotus root and its nodes as a key variable, along with other ingredients, to conduct single-factor analyses and formulation optimization. The goal is to design a low-fat, high-fiber cookie that reduces excessive sweetness in baked goods and enhances satiety [14].

2. Materials and methods

2.1. Materials and reagents

Fresh lotus roots were purchased from Wuhé Vegetable Market, Nanning; low-gluten flour was obtained from Yanjin Kemin Flour Co., Ltd.; butter was provided by Fonterra Trading (Shanghai) Co., Ltd.; powdered sugar was from Guangzhou Beiledao Co., Ltd.; neutral papain (enzyme activity 10,000 U/g) from Nanning Chenze Co., Ltd.; liquid heat-resistant food-grade α-amylase (enzyme activity 150,000 U/mL) from Nanning Chenze Co., Ltd.; glucoamylase (enzyme activity 100,000 U/mL) from Nanning Chenze Co., Ltd.; 95% edible ethanol was also sourced from Nanning Chenze Co., Ltd.

2.2. Instruments and equipment

Electric thermostatic blast drying oven (DHG-9053A): Shanghai Jinghong Laboratory Equipment Co., Ltd.; electronic balance (BSA224S): Sartorius Scientific Instruments (Beijing) Co., Ltd.; digital thermostatic water bath (HH-4): Changzhou Guohua Electric Appliance Co., Ltd.; electronic moisture analyzer (DSH-50-1): Shanghai Yueping Scientific Instruments (Suzhou) Co., Ltd.; texture analyzer (CT3-10K): Brookfield; low-speed multi-tube automatic balanced centrifuge (TDZ5-WS): Hunan Xiangyi Laboratory Instrument Development Co., Ltd.

2.3. Process flow

2.3.1. Total dietary fiber extraction

The method of Li [15] was slightly modified. Briefly: 20 g of lotus root powder was weighed and added to 480 mL of 3.38% citric acid solution, then incubated in a 72 °C water bath for 70 min. The pH was adjusted to 4.5, followed by the addition of 1 mL α-amylase and enzymatic hydrolysis at 95 °C for 35 min. Then, 0.4 mL glucoamylase was added and hydrolyzed at 60 °C for 30 min. After adjusting the pH to 7, 1 mL neutral papain was added and hydrolyzed at 40 °C for 90 min. Enzyme inactivation was performed in a boiling water bath for 10 min, and the mixture was cooled to room temperature. Four volumes of 95% ethanol were added and left overnight. The precipitate was collected, repeatedly washed with absolute ethanol, dried at 65 °C for 5 h, and weighed.

2.3.2. Cookie preparation process

Butter was melted and whipped, followed by the gradual addition of egg white while mixing. Powdered sugar was sifted and added in three portions, mixed thoroughly, and then total dietary fiber powder was incorporated. Low-gluten flour was sifted and added in three portions, and the dough was kneaded and shaped. The dough was rolled and imprinted, then preheated in the oven and baked. After cooling, the final cookies were obtained.

2.4. Analytical methods

2.4.1. Determination of total dietary fiber yield

The acid–enzyme method described by Zhang [16] was slightly modified to extract total dietary fiber from lotus residue and nodes. The extraction yield was calculated as:

TDF Extraction Rate (%) = Dry Weight of Sample (g)/Mass of Lotus Root Powder (g)

2.4.2. Sensory evaluation

According to GB/T 20980-2021 “National Food Safety Standard: Cookies” [17], 50 sensory panelists with no specific preferences evaluated the cookies in terms of appearance, texture, taste, color, and aroma. The evaluation criteria are shown in Table 1.

Table 1. Sensory evaluation criteria for cookies

Attribute	Criteria	Score
	Full shape, clear surface patterns, no shrinkage or deformation bubbles	12~15
Appearance (15 points)	Moderately full, slightly unclear patterns, incomplete slices, some damage	9~11
	Not full, blurred patterns, surface bubbles, severely broken	0~8
	Dense, porous cross-section, no large holes, no powder	16~20
Texture (20 points)	Slightly hard, some large holes, minor powder	11~15
	Hard, unevenly distributed holes, obvious large holes and powder	0~10
	Crisp, non-sticky, smooth, appropriate sweetness	25~30
Taste (30 points)	Moderately crisp, slightly sticky, minor roughness, acceptable sweetness	19~24
	Hard, sticky, rough, poor sweetness	0~18
	Even golden-yellow, no over-browning, no white spots	12~15
Color (15 points)	Light yellow, minor burnt areas or white spots	9~11
	Uneven yellow-brown, burnt or over-white areas	0~8
	Strong fragrance, no off-flavors	16~20
Aroma (20 points)	Moderate aroma, no off-flavors	11~15
	Weak or rancid/off flavors	0~10

2.4.3. Effect of total dietary fiber particle size on water-holding capacity

Following a modified method of Liang [18], 1 g of sifted sample was placed in a 100 mL conical flask, 30 mL distilled water was added, and the mixture was shaken for 1 h at 2000 rpm. After shaking, the solution was transferred to a 50 mL centrifuge tube; residual solids in the flask were rinsed with a small amount of distilled water into the tube. Samples were centrifuged at 5000 rpm for 10 min, the supernatant was decanted, and the wet weight (M1) was recorded. Samples were then dried in an oven to a constant weight (M). Water-holding capacity was calculated as:

$$Water - holding\, capacity(g/g) = (M_1 - M)/M \quad (1)$$

2.4.4. Effect of total dietary fiber particle size on swelling capacity

A modified method from Sowbhagy [19] was used. One gram of sifted sample was placed in a 10 mL graduated cylinder, and its initial volume V_1(mL) was recorded. Ten milliliters of distilled water were added, mixed, and the cylinder was incubated at 25 °C for 24 h. The final volume V_2(mL) of the swollen soluble dietary fiber was recorded. Swelling capacity was calculated as:

$$Swelling\ capacity\left(mL/g\right)=\frac{V_2-V_1}{m} \quad (2)$$

2.4.5. Effect of total dietary fiber addition on cookie texture

Referring to Zhang [20] with slight modifications, cookie samples were prepared using 100 g flour, 25 g butter, 30 g powdered sugar, 25 g egg, and total dietary fiber additions of 0%, 7%, 9%, 11%, 13%, and 15%, yielding six groups. After baking and cooling, cookies were stored in sealed bags in a desiccator. Texture measurements of hardness, crispness, and breakability were performed using a texture analyzer with a TA-7 probe and TA-JTPB fixture. Pre-test speed = 1.0 mm/s, test speed = 0.5 mm/s, post-test speed = 1.0 mm/s, compression = 50%, hold time = 5 s. Each group was tested five times.

2.4.6. Microbiological and other physicochemical analyses

Physicochemical and microbiological parameters of the finished cookies were analyzed according to GB 7100-2015 “National Food Safety Standard: Cookies” [16].

2.5. Single-factor experimental design for total dietary fiber cookies

Following the process described in Section 1.3, cookies were prepared using 100 g of flour and 25 g of egg. Sensory evaluation, water-holding capacity, and swelling capacity were used as evaluation indices. The effects of four single factors on cookie quality and sensory scores were investigated: total dietary fiber particle size (A), total dietary fiber addition level (B), powdered sugar addition (C), and butter addition (D).

2.6. Orthogonal experimental design

Sensory score was selected as the evaluation index for the orthogonal experiment. The four factors were arranged in an $L_9(3^4)$ orthogonal design. The factors and their levels are shown in Table 2.

Table 2. Level code of orthogonal test factors for process optimization of dietary fiber biscuit

Level	Total dietary fiber particle size (A)	Total dietary fiber addition (B)	Powdered sugar addition (C)	Butter addition (D)
1	1 (140 mesh)	1(9%)	1(25 g)	1(25 g)
2	2 (160 mesh)	2(11%)	2(30 g)	2(30 g)
3	3 (180 mesh)	3(13%)	3(35 g)	3(35 g)

3. Results and analysis

3.1. Extraction yield of total dietary fiber from lotus root

Using the acid–enzyme method, the total dietary fiber yield from lotus nodes is approximately 53% [3], while enzymatic hydrolysis of lotus residue yields about 42.27% [17]. In this study, the acid–enzyme method was applied to extract total dietary fiber from both lotus residue and nodes, resulting in an extraction yield of approximately 48.56%.

3.2. Analysis of single-factor and orthogonal experiment results for lotus-root total dietary fiber cookies

3.2.1. Effect of total dietary fiber particle size on physical properties of cookies

As shown in Figure 1, the particle size of total dietary fiber significantly affects sensory evaluation, water-holding capacity, and swelling capacity of the cookies. When the particle size is 100 mesh, the cookies exhibit a noticeable gritty texture and minor white spots on the surface. For particle sizes ≥120 mesh, the cookies show no gritty sensation, which is preferable, indicating that the total dietary fiber particle size should be ≥120 mesh. Although sensory attributes such as taste and aroma do not differ significantly for particle sizes ≥120 mesh, water-holding capacity and swelling capacity are notably affected. Swelling capacity tends to increase as the particle size decreases, but when the sieved particle size exceeds 160 mesh, both water-holding capacity and swelling capacity decrease. Cao [21] observed similar results in pea dietary fiber: smaller fiber particles, when mixed with flour, exhibited higher water absorption and greater surface area, leading to increased volume after swelling and enhanced swelling capacity. However, excessively small particles reduced hydration capacity, compromising dough stability.

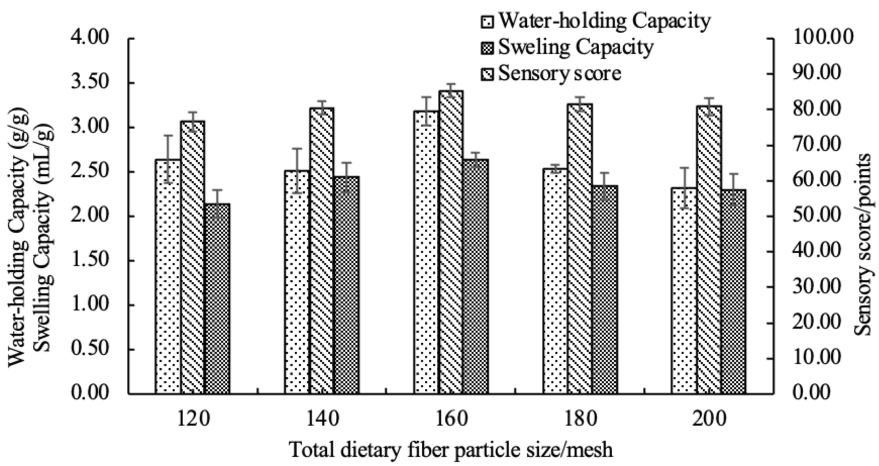

Figure 1. Influence of total dietary fiber particle size on water-holding capacity, swelling capacity, and sensory evaluation of cookies

Dietary fiber possesses inherent water-holding and swelling properties, which positively influence the quality of baked products [22]. High water-holding and swelling capacities of total dietary fiber can effectively increase the volume of chyme and feces, accelerate bowel movements, prevent constipation, and reduce the risk of colon cancer [5].

3.2.2. Effect of total dietary fiber addition level on physical properties of cookies

As shown in Figure 2, varying the addition level of total dietary fiber affects sensory evaluation, water-holding capacity, and swelling capacity of the cookies. Sensory scores and swelling capacity initially increase with higher dietary fiber content but decrease when the addition exceeds 11%. When the addition exceeds 13%, the dough becomes harder, the resulting cookies are coarser in texture, and sensory scores decline. Water-holding capacity increases with dietary fiber addition due to higher dough water absorption, which alters the powder state of the dough. However, excessive dietary fiber can reduce the protein content of the dough, impair gluten network formation, increase dough hardness, and produce uneven and overly large pores in the cookies, negatively impacting appearance and texture [23].

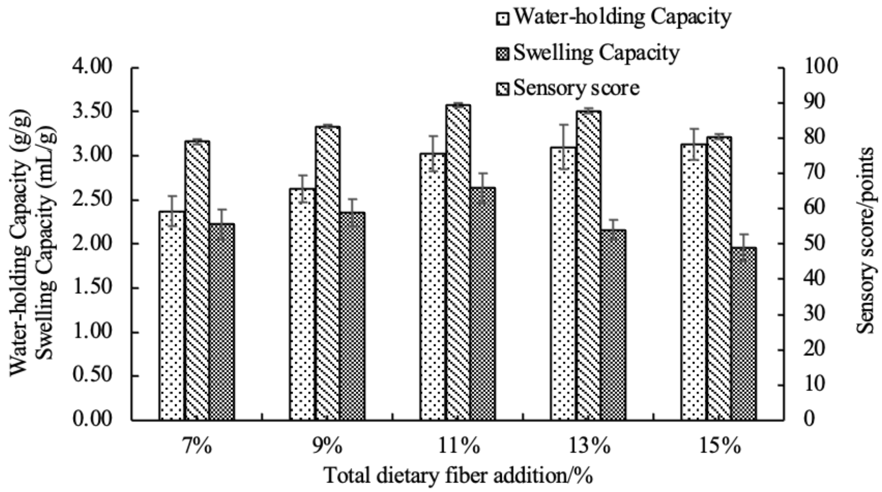

Figure 2. Influence of total dietary fiber addition on water-holding capacity, swelling capacity, and sensory evaluation of cookies

Sun [24] reported that cookies prepared with 6% citrus peel dietary fiber (based on 100 g of low-gluten flour) exhibited complete shape and crisp texture. In this study, when the total dietary fiber addition reached 11%, cookies achieved optimal texture and color, with relatively high water-holding capacity and swelling capacity.

3.2.3. Effect of powdered sugar addition on physical properties of cookies

As shown in Figure 3, varying the amount of powdered sugar affects sensory evaluation, water-holding capacity, and swelling capacity. Overall, sensory scores first increase and then decrease with increasing sugar content, while changes in water-holding capacity and swelling capacity are relatively moderate. When 30 g of powdered sugar is added, water-holding capacity is optimal, swelling capacity is favorable, sweetness is moderate, baked color is ideal, aroma is strong, and texture is crisp. Adding too little sugar results in bland cookies with insufficient Maillard reaction, producing pale-colored cookies. Excessive sugar leads to overly sweet cookies with pronounced Maillard reaction [10], darkening the surface to a brownish-yellow color. Both insufficient and excessive sugar negatively affect cookie texture and color.

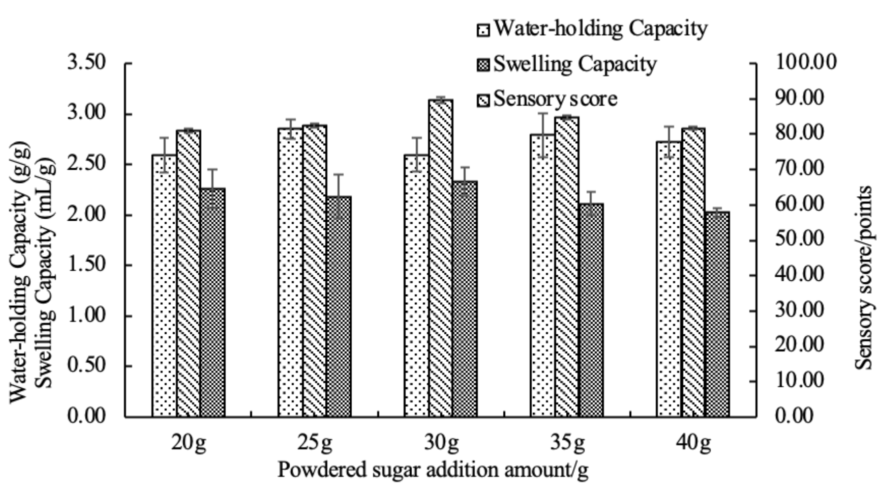

Figure 3. Influence of powdered sugar addition on water-holding capacity, swelling capacity, and sensory evaluation of cookies

3.2.4. Effect of butter addition on physical properties of cookies

As shown in Figure 4, increasing butter content improves dough softness, delays starch retrogradation, enhances crispness and palatability, and extends shelf life. Butter addition significantly affects cookie appearance and aroma [25]. Sensory scores and swelling capacity initially increase with butter content, then decrease at higher levels. Too little butter results in strong dough water-holding capacity but incomplete network structure, producing hard, coarse, and dry cookies. Excessive butter makes cookies greasy with a heavy flavor; higher fat–water interaction reduces swelling capacity, softens dough, increases cookie gaps, and lowers sensory scores. Optimal butter addition (30 g) yields cookies with golden color, crisp texture, good water-holding capacity, and favorable swelling properties.

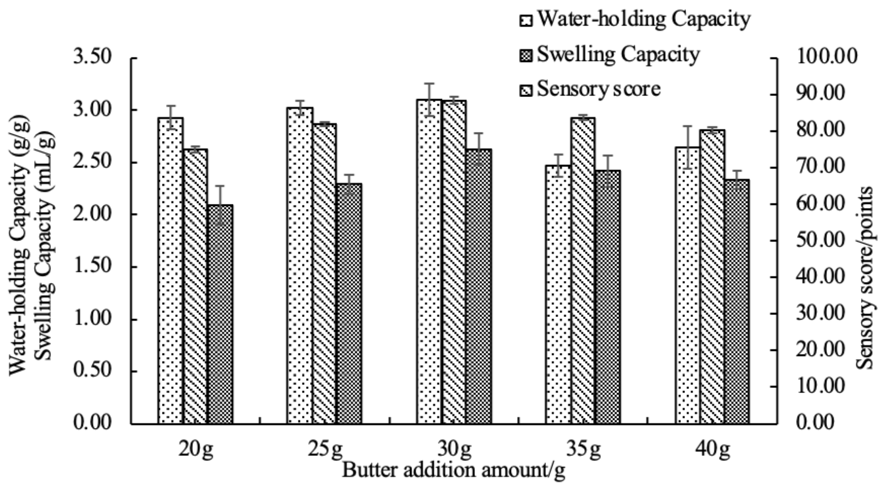

Figure 4. Influence of butter addition on water-holding capacity, swelling capacity, and sensory evaluation of cookies

3.2.5. Orthogonal experiment results and analysis for lotus-root total dietary fiber cookies

As shown in Table 3 and Table 4, the influence of four factors on cookie quality follows the order: total dietary fiber particle size > powdered sugar addition > butter addition > total dietary fiber addition (A > C > D > B). The optimal combination from the orthogonal test is $A_2B_2C_3D_2$: total dietary fiber particle size 160 mesh, total dietary fiber addition 11%, powdered sugar 35 g, and butter 30 g. The combination with the highest sensory score in the orthogonal test was $A_2B_2C_3D_1$, differing only in butter content (25 g instead of 30 g). Considering the aim to produce a healthier cookie, 25 g of butter was chosen for the final formulation.

Table 3. Orthogonal test analysis of optimal formulation

Treatment	Fiber Particle Size (A)	Fiber Addition (B)	Sugar Addition (C)	Butter Addition (D)	Sensory Score (X±S)
1	1	1	1	1	63.38±1.26
2	1	2	2	2	74.30±0.78
3	1	3	3	3	79.15±0.82
4	2	1	2	3	88.61±1.39
5	2	2	3	1	93.84±1.07
6	2	3	1	2	87.65±0.85
7	3	1	3	2	86.92±0.94
8	3	2	1	3	80.46±0.96
9	3	3	2	1	81.69±1.10
K_1	216.84	238.92	231.48	238.92	
K_2	270.09	248.61	244.59	248.88	
K_3	249.06	248.49	259.92	248.22	
k_1	72.28	79.64	77.16	79.64	
k_2	90.03	82.87	81.53	82.96	
k_3	83.02	82.83	86.64	82.74	
R	17.76	3.23	9.47	3.32	
Influence			A>C>D>B		
Optimal Combination			$A_2B_2C_3D_2$		

Table 4. Analysis of variance for optimal formulation

Source of Variation	df	Mean Square	F Value	Significance
A	2	239.965	23.185	*
B	2	10.316	0.997	
C	2	67.442	6.516	
D	2	17.442	1.371	
Error	2	10.350		
Total	10			

Note: "**" indicates extremely significant effect ($P < 0.01$), and "*" indicates significant effect ($P < 0.05$).

3.3. Effect of total dietary fiber addition on cookie texture

As shown in Figure 5, with increasing total dietary fiber addition, both crispness and hardness of the cookies initially increase. However, when fiber content reaches 13%, these values begin to decrease. This is because changes in the dough's network structure enlarge the pores and increase water mobility, altering its texture and initially enhancing crispness and hardness [26]. As total dietary fiber content increases, the proportion of gluten, which provides structural support in the dough, becomes diluted. This weakens the dough network, reduces elasticity, and leads to a decline in both crispness and hardness. When fiber content reaches 15%, the insoluble dietary fiber retains water, improving the dough's water-holding capacity, which in turn reduces hardness and crispness. Previous studies indicate that cookies with crispness between 870–2500 g have increasingly crisp textures as the value rises, and hardness between 835–2100 g slows the staling rate as it increases [27]. In this study, cookies with 11% total dietary fiber exhibited optimal crispness and texture, making it a desirable addition level.

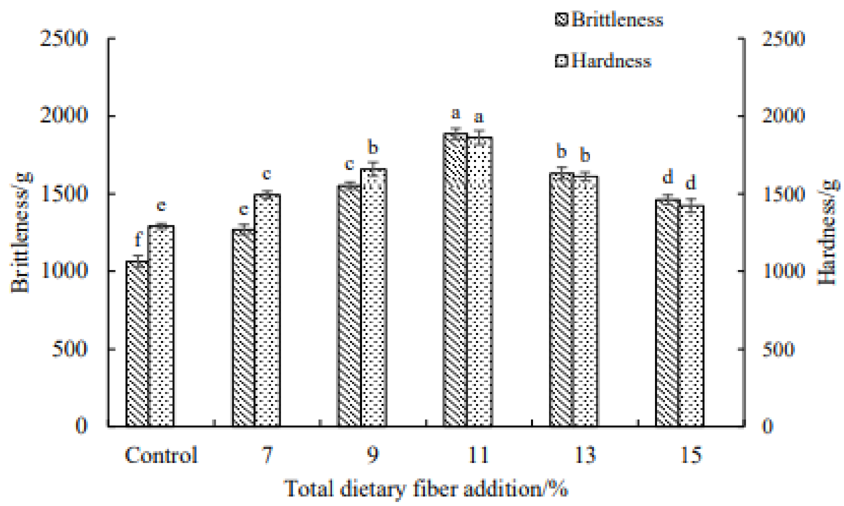

Figure 5. Influence of total dietary fiber addition on cookie crispness and hardness

3.4. Effect of total dietary fiber addition on physicochemical properties of cookies during storage

3.4.1. Effect on acid value

Figure 6 shows the influence of total dietary fiber addition on acid value during storage. The acid value of all cookies gradually increased over time, with the blank group exhibiting the most pronounced rise. Within the first 14 days, cookies containing dietary fiber showed a relatively slow increase in acid value, while after day 14, the acid values rose significantly. After day 21, the acid value increase in the blank group became more pronounced compared to fiber-enriched cookies. By day 28, cookies in the blank group and those with 7% or 9% fiber addition showed a more significant acid value increase than cookies containing 11%, 13%, or 15% fiber. On day 28, cookies with 11%, 13%, and 15% fiber had acid values below 1.5 mg/g, whereas the blank group exceeded 2.5 mg/g. These results indicate that adding total dietary fiber helps inhibit acid value increases and extends the shelf life of cookies.

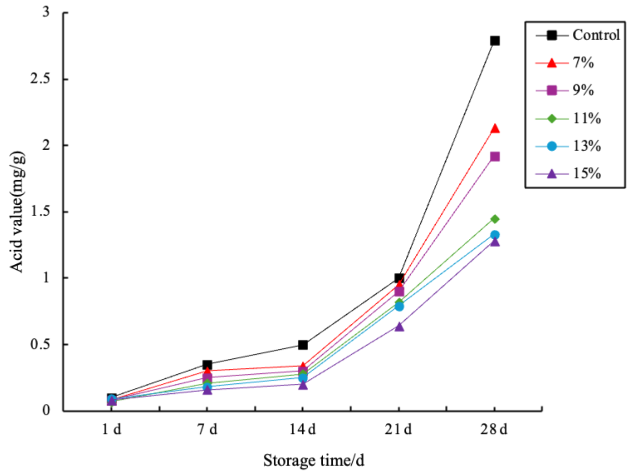

Figure 6. Changes in acid value of cookies with different total dietary fiber levels during storage

3.4.2. Effect on peroxide value

As shown in Figure 7, the effect of total dietary fiber addition on the peroxide value of cookies during storage was significant. According to the national hygiene standard for cookies (0.25 g/100 g), the peroxide value of the blank group gradually increased over time. After day 14, the blank group exhibited the most pronounced increase, and by day 21, the peroxide value was close to the standard limit of 0.25 g/100 g. By day 28, the blank group exceeded the national standard.

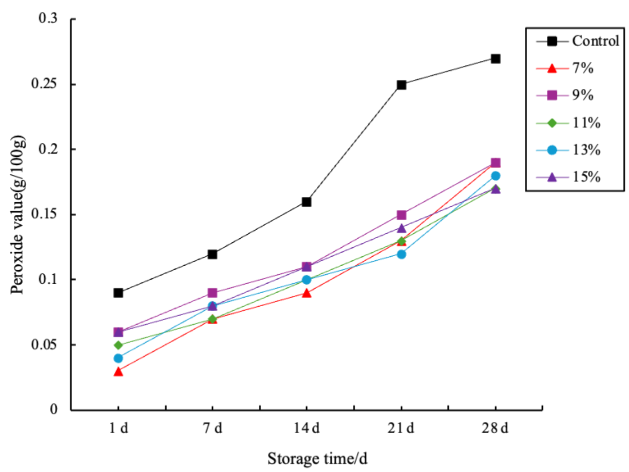

Figure 7. Changes in peroxide value of cookies with different total dietary fiber levels during storage

Cookies containing varying proportions of total dietary fiber exhibited lower peroxide values than the blank group throughout storage, and the rate of increase was slower. On day 28, the experimental groups with 13% and 15% fiber had lower peroxide values than those with 7%, 9%, and 13% fiber.

All cookies with added dietary fiber maintained peroxide values below the national limit on day 28, indicating that total dietary fiber effectively enhances the cookies' resistance to spoilage and oxidative deterioration. Zhang [28] reported that dietary fiber extracted from green wheat bran using a dual-enzyme method exhibited a free radical scavenging capacity of up to 80%.

3.5. Physicochemical and microbiological indicators of lotus root total dietary fiber cookies

The physicochemical and microbiological quality of lotus root total dietary fiber cookies was assessed according to GB/T20980-2021 “National Food Safety Standard for Cookies” [16]. The results are summarized in Table 5, showing that all indicators were within the national standard limits.

Table 5. Hygiene and quality indicators of cookies

Indicator	Reference Standard	Standard Limit	Result
Total colony count (CFU/g)	GB4789.2-2022	<750	430
Moisture content (g/100 g)	GB5009.3-2016	<4%	2.7%
Peroxide value (fat basis) (g/100 g)	GB5009.227-2016	≤0.25	0.20
Acid value (fat basis) (KOH) (mg/g)	GB5009.229-2016	≤5	2.1

4. Conclusions

With increasing health awareness, high dietary fiber cookies have become increasingly popular. Based on single-factor experiments and subsequent orthogonal optimization, the optimal formulation parameters for cookies were determined as follows: 100 g low-gluten flour, 25 g egg liquid, total dietary fiber passed through a 160-mesh sieve, total dietary fiber addition 11%, powdered sugar 35 g, and butter 25 g. Under these conditions, the cookies had uniform shape, golden color, crisp texture with moderate hardness, rich aroma, and a moderate level of sweetness. They are a high-fiber product suitable for general consumer preferences. This study provides a new approach for the comprehensive utilization of lotus root and rhizome segments, enhancing the added value of lotus products, increasing the economic benefit of lotus roots and rhizomes, and reducing resource waste and environmental pollution.

Funding project

Guangxi University of Chinese Medicine 2024 National College Student Innovation and Entrepreneurship Training Program (Project No. 202410600025)

References

[1] Zhang, Y., Lu, X., & Zeng, S. (2015). Nutritional composition, physiological functions and processing of lotus (Nelumbo nucifera Gaertn.) seeds: A review. *Phytochemistry Reviews, 14*, 321–334.

[2] Chiang, P. Y., & Luo, Y. Y. (2007). Effects of pressurized cooking on the relationship between the chemical compositions and texture changes of lotus root (Nelumbo nucifera Gaertn.). *Food Chemistry, 105*(2), 480–484.

[3] Jin, W. (2016). Preparation of dietary fiber from lotus rhizome and its effect on weight control (Master’s thesis). Huazhong Agricultural University, Wuhan.

[4] Li, P., & Liu, Z. (2020). Dietary nutrition and chronic kidney disease. *Journal of Nephrology and Dialysis Kidney Transplantation, 29*(1), 66–70.

[5] Jiam, C., & Liu, X. (2019). Structural characteristics and functional properties of soluble dietary fiber from defatted rice bran obtained through Trichoderma viride fermentation. *Food Hydrocolloids, 94*, 468–474.

[6] Zhang, W., Zeng, G., & Pan, Y. (2017). Properties of soluble dietary fiber-polysaccharide from papaya peel obtained through alkaline or ultrasound-assisted alkaline extraction. *Carbohydrate Polymers, 172*, 112–120.

[7] Wolfram, T., & Ismail-Beigi, F. (2011). Efficacy of high-fiber diets in the management of type 2 diabetes mellitus. *Endocrine Practice, 17*(1), 132–142.

[8] Wu, J., Wang, H., & Zhang, X. (2006). Content and characteristic evaluation of lotus root dietary fiber prepared by three methods. *Modern Food Science and Technology, 22*, 71–77.

[9] Ilam, A. J. M., Civitarese, A. E., & Hesslink, R. L. (2012). Viscous dietary fiber reduces adiposity and plasma leptin and increases muscle expression of fat oxidation genes in rats. *Obesity (Silver Spring, MD), 20*(2), 349–355.

[10] Wu, L. (2020). Preparation, functional properties of wheat bran soluble dietary fiber and its application in biscuits (Master's thesis). Jiangsu University.

[11] Liu, Y., Zhang, G., & Zhang, K. (2020). Functional properties of dietary fiber and research progress in biscuits. *Grain Processing, 45*(5), 64–69.

[12] Du, J. H., Fu, Y. C., & Wang, N. (2009). Effects of aqueous chlorine dioxide treatment on browning of fresh-cut lotus root. *LWT-Food Science and Technology, 42*(2), 654–659.

[13] Gao, X. (2021). Extraction of insoluble dietary fiber from red dates and its lead ion adsorption properties and application in biscuits (Master's thesis).

[14] Fang, D., & Zheng, Y. (2019). Optimization of bamboo shoot dietary fiber modification by composite enzymatic method and evaluation of physicochemical properties. *Journal of Fujian Agriculture, 3,* 364–370.

[15] Li, X. (2021). Drying, modification, and application of lotus residue dietary fiber (Master's thesis). Hebei Agricultural University.

[16] National Health and Family Planning Commission of China. (2015). GB 7100–2015 National food safety standard: Biscuits [Standard]. Beijing: China Standards Press.

[17] Zhang, Z., & Zhang, H. (2013). Study on extraction process of pomelo peel dietary fiber. *Journal of West Anhui University, 5*, 82–84.

[18] Liang, X. H., Ran, J. J., & Sun, J. K. (2018). Steam-explosion-modified optimization of soluble dietary fiber extraction from apple pomace using response surface methodology. *CYTA – Journal of Food, 16*(1), 20–26.

[19] Sowbhagya, H. B., Suma, P. F., & Mahadevamma, S. (2007). Spent residue from cumin – A potential source of dietary fiber. *Food Chemistry, 104*(3), 1220–1225.

[20] Zhang, Z., Wei, C., & Huang, Y. (2018). Development and texture characteristics of okra biscuits. *Grain and Feed Industry, 5*, 25–27, 33.

[21] Cao, Z., Liu, J., & Ma, Y. (2021). Effect of pea dietary fiber particle size on dough and bread quality. *Food Research and Development,* (19), 8–12.

[22] Wang, J., Li, C., & Lu, X. (2023). Physiological functions, preparation methods, and applications of dietary fiber in food processing. *Preservation and Processing, 4*, 74–80.

[23] Deng, Y., & Qiu, S. (2022). Effects of cereal dietary fiber on quality of Chinese and Western flour products: Research progress. *Agricultural Products Processing, 547*(5), 80–82, 90.

[24] Sun, H. (2016). Application of citrus peel dietary fiber in cookies. *Preservation and Processing, 16*(6), 69–74.

[25] Wang, T. (2022). Characteristics of quinoa dietary fiber and preparation of quinoa cookies (Master's thesis). Chengdu University.

[26] Wang, L., & Wang, M. (2014). Application of lemon peel dietary fiber in biscuits. *Food and Fermentation Technology, 50*(1), 51–55.

[27] Chung, S. Y., Han, S. H., & Lee, S. W. (2019). Effect of Maillard reaction products prepared from glucose-glycine model systems on starch digestibility. *Starch – Stärke, 64*(8), 756–764.

[28] Zhang, K., Wen, Q., & Wang, J. (2017). Extraction and antioxidant activity of dietary fiber from green wheat bran. *Henan Agricultural Sciences, 46*(12), 139–143.