Hindawi
Journal of Food Quality
Volume 2018, Article ID 4931202, 11 pages
https://doi.org/10.1155/2018/4931202

*Research Article*

# Influence of the Addition of Potato, Okara, and Konjac Flours on Antioxidant Activity, Digestibility, and Quality of Dumpling Wrappers

**Yongli Jiang, Yimeng Zhao, Danfeng Wang, and Yun Deng**

*Department of Food Science and Technology, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai 200240, China*

Correspondence should be addressed to Yun Deng; y_deng@sjtu.edu.cn

Received 6 September 2018; Revised 24 October 2018; Accepted 31 October 2018; Published 21 November 2018

Academic Editor: Antonio Piga



To improve the antioxidant activity (AA), digestibility, and quality of fiber-rich dumpling wrappers, potato, okara, and konjac flours were added to wheat flour. The contents of these additional ingredients in the dumpling wrapper were optimized using the response surface methodology and the synthetic evaluation method. The dietary fiber content (DFC) and AA of blend flours and the optimized cooking time (OCT), cooking loss (CL), hardness, chewiness, firmness, color, and sensory evaluation (SE) of dumpling wrappers were evaluated as response quality parameters. The optimized flour was identified containing 17.5 g of potato flour, 8.5 g of okara flour, and 1.2 g of konjac flour per 100 g of blend flour, which resulted in a higher synthetic evaluation index value (0.71 compared with 0.68 for wheat flour). The qualities of the optimized flour dumpling wrappers were compared with those of wheat flour dumpling wrappers to verify the practicality of the optimized flour. The results showed that the optimized flour showed better comprehensive qualities, especially regarding DFC (9.59%, fourfold higher than that of wheat flour) and AA. Furthermore, the predicted glycemic index (GI) of the optimized flour (74.93%) was lower than that of the wheat flour (81.47%). Overall, the addition of potato, okara, and konjac flours can significantly ($P < 0.05$) improve DFC, AA, and digestibility of wheat flour. The optimized flour not only maintains excellent dumpling wrapper quality but also increases the utilization of potato and okara flours, which has great potential for industrial applications.

## 1. Introduction

Food fortification is widely applied to fulfil consumer demand for nutritional requirements [1, 2]. The role of diet in the prevention of human ailments, such as cancer, cardiovascular diseases, and obesity, has become the first-line approach for consumers [3, 4]. Natural raw materials rich in dietary fiber and high in antioxidants serve as functional ingredients in the food industry [5, 6].

Okara is the by-product of the production of soya bean foods, with about 14 million tons of okara generated annually worldwide [7]. Dry okara is rich in protein (25%), lipids (10%), fibers (50%), and other nutrients, including isoflavones, lignans, and phytosterols [8]. These compounds have antioxidant and anti-inflammatory activities, can prevent cardiovascular diseases and gastrointestinal problems, and can protect against several cancers [8, 9]. Therefore, okara has great potential as a natural functional substance for producing healthy food products.

Konjac (*Amorphophallus konjac*) is a major vegetable (tuber) crop grown in Asian countries. Konjac is associated with health benefits such as providing no caloric value, controlling weight gain, improving intestinal activity to alleviate constipation and satiation, and lowering blood cholesterol and triglycerides [10]. Konjac has been extensively used as a food additive and dietary supplement and has been authorized in Europe and classified as generally recognized as safe (GRAS) by the Food and Drug Administration (FDA) [11].

Potato (*Solanum tuberosum*) is another important food crop globally, which is not only an important supplier of carbohydrates in the human diet but also a key supplier of dietary nutrients, including antioxidants, minerals, protein, and vitamins [6]. Potato flour can be mixed at contents of 2–20% with wheat flour to improve the interior qualities of bread, such as texture, aroma, and flavor, without significantly affecting external attributes [12].

Dumplings are an important traditional food in China, comprising a dough wrapper filled with minced meat or mixed with chopped vegetables [13]. Dumpling quality is determined by both the characteristics of the wrapper flour and filling. Therefore, improving the flour quality can play an important role in improving the dumpling quality [13, 14]. In recent decades, dumpling wrappers have mainly been produced from wheat flour. Consumers are becoming more nutrition and health conscious, preferring diets that provide good tastes, are reasonably priced, and contain functional ingredients, such as dietary fiber and antioxidant-rich substances [15]. Furthermore, the short supply and higher price of wheat flour have forced manufacturers to search for new formulations for next-generation flour products that are higher in dietary fiber, of higher quality, and cheaper [5, 16]. Accordingly, the incorporation of potato, okara, and konjac flours into dumpling wrappers would enhance their nutritional and functional qualities.

Researchers have previously attempted to improve the nutritional value of flour products, such as bread and biscuits, by adding rice, legume flour, tuberous roots, oats, corn, wheat germ, barley, fiber, and polyphenols [15, 17]. This study aimed at optimizing the formulation of a functional flour composed of wheat, potato, okara, and konjac flours, and to determine the various attributes that influence the flour and dumpling wrapper qualities, such as DFC, AA, OCT, CL, texture, color, and sensory profile.

## 2. Materials and Methods

*2.1. Raw Materials and Reagents.* Wheat flour (moisture: 11.12%; protein: 11.74%; starch: 66.79%; ash: 0.35%; dietary fiber: 2.14%) was purchased from Weifang Kite Flour Co., Ltd. (Shandong, China). Potato flour (moisture: 7.73%; protein: 8.11%; starch: 77.82%; ash: 2.07%; dietary fiber: 12.93%) was purchased from Wuxi Beijing Starch Co., Ltd. (Jiangsu, China). Okara flour (moisture: 8.37%; protein: 23.64%; starch: 1.47%; ash: 2.03%; dietary fiber: 51.86%) was purchased from Shandong Zhaoyuan Wen Kee Food Co., Ltd. (Shandong, China). Konjac flour (moisture: 10.46%; protein: 4.18%; starch: 0.58%; ash: 4.77%; dietary fiber: 74.40%) was purchased from Hanzhong Kowloon Lu Xin Konjac Flour Co., Ltd. (Sichuan, China).

1,1-Diphenyl-2-picryl-hydrazyl (DPPH) were obtained from Sigma-Aldrich (USA). All chemicals used were of analytical grade.

*2.2. Experimental Design.* According to our previous single-factor experiment about effects of potato, okara, and konjac flours on physicochemical properties of wheat flour, the flours containing 20.00 g of potato flour, 10.00 g of okara flour, and 1.00 g of konjac flour per 100.00 g of blended flour showed better nutritional quality and processing properties. In order to optimize dumpling wrapper of blended flour formulation, a Box–Behnken design including 15 experimental runs formed by three variables and three levels was used (Table 1). The process variables consisted of potato, okara, and konjac flours, and the level of each variable was set according to the aforementioned single-factor experiment. Response surface methodology (RSM) was used to analyze the effects of process variables on DFC and AA of the blended flour, OCT, CL, color, hardness, chewiness, firmness, and SE of the dumpling wrapper.

*2.3. Chemical Compositions of Blend Flours.* Moisture, protein, ash, and dietary fiber contents were determined using an AOAC official method (AOAC 2008) [18]. Starch content was determined using a total starch assay kit (Megazyme, K-TSTA), purchased from Shanghai Threebio Technology Co., Ltd (Shanghai, China).

*2.4. Antioxidant Activity (AA) of Blend Flours.* The AA of blend flours was measured according to the reports of Wang et al. [9]and Hu et al. [19] with slight modifications. The sample (1 g) was added to ethyl alcohol (25 mL, 70%, v/v), sonicated for 30 min (S10H, Zealway Instrument Co., Ltd., China), and centrifuged for 10 min (16,000 × g; Z-326 K, Hermle Labortechnik GmbH, Germany). The supernatant was collected, evaporated to remove ethyl alcohol using a vacuum rotavap (RE-52AA, Shanghai Qingpu Huxi Instrument, China), and then diluted to 50 mL with distilled water to give the sample extract solution.

*2.4.1. AA from DPPH Inhibition.* Sample extract solution (0.75 mL) was added to a DPPH–methanol solution (1.5 mL, 0.09 mg/mL) and incubated in dark for 30 min at room temperature. Absorbance was measured at 517 nm in a microplate reader (Multiskan1510, Thermo Fisher Scientific Co., Ltd., China). The results were calculated using the following equation:

$$\text{DPPH} = \left(1 - \frac{A_s}{A_c}\right) \times 100, \tag{1}$$

where inhibition represents the DPPH radical-scavenging activity (%), $A_s$ is the absorbance of the sample, and $A_c$ is the absorbance of the control (water).

*2.4.2. AA from Reducing Power (RP) Inhibition.* Sample extract solution (1 mL) was mixed with sodium phosphate buffer (2.5 mL, 0.2 mol/L, pH 6.6) and aqueous potassium ferricyanide (2.5 mL, 10.0 g/L in water). After incubating for 20 min at 50°C, trichloroacetic acid (2.5 mL, 0.1 kg/L) was added. A 2.5 mL aliquot of the mixture was mixed with distilled water (2.5 mL) and aqueous ferric chloride (0.5 mL, 1.0 g/L) after incubating for 10 min at room temperature. The absorbance at 700 nm was expressed as RP.

*2.5. Dumpling Wrapper Preparation.* Dumpling dough was prepared by mixing flour (100 g) with distilled water (45 mL)

Table 1: Experimental values of response variables and synthetic evaluation index for response surface design[1].

| Experimental runs | Variables | | | DFC (%) | DPPH (%) | OCT (min) | CL (%) | Firmness (N) | Hardness (N) | Chewiness (N·mm) | Color | SE | *S* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Potato | Okara | Konjac | | | | | | | | | | |
| 1 | 15 | 7.5 | 1 | 8.21 ± 0.43 | 49.41 ± 2.38 | 2.67 ± 0.00 | 3.98 ± 0.33 | 0.94 ± 0.08 | 15.60 ± 0.52 | 12.18 ± 0.56 | 1.78 ± 0.05 | 73.11 ± 1.00 | 0.66 |
| 2 | 25 | 7.5 | 1 | 9.19 ± 0.87 | 46.12 ± 0.62 | 2.50 ± 0.20 | 4.10 ± 0.23 | 1.09 ± 0.04 | 11.99 ± 0.54 | 9.29 ± 0.62 | 2.46 ± 0.04 | 66.72 ± 2.63 | 0.38 |
| 3 | 15 | 12.5 | 1 | 10.63 ± 0.27 | 47.68 ± 0.65 | 2.89 ± 0.13 | 3.97 ± 0.39 | 1.31 ± 0.09 | 11.61 ± 0.23 | 6.97 ± 0.37 | 1.45 ± 0.01 | 64.22 ± 3.07 | 0.40 |
| 4 | 25 | 12.5 | 1 | 11.78 ± 0.60 | 47.22 ± 0.90 | 2.56 ± 0.17 | 5.45 ± 0.34 | 1.23 ± 0.10 | 10.51 ± 0.14 | 7.23 ± 0.21 | 2.55 ± 0.04 | 60.94 ± 1.10 | 0.21 |
| 5 | 15 | 10 | 0.8 | 9.41 ± 0.19 | 46.72 ± 0.56 | 2.67 ± 0.00 | 4.35 ± 0.08 | 1.01 ± 0.04 | 13.66 ± 0.79 | 10.58 ± 0.83 | 0.74 ± 0.08 | 71.44 ± 2.96 | 0.64 |
| 6 | 25 | 10 | 0.8 | 10.54 ± 0.13 | 50.01 ± 0.18 | 2.67 ± 0.00 | 5.27 ± 0.54 | 1.02 ± 0.09 | 11.56 ± 0.33 | 8.04 ± 0.08 | 2.18 ± 0.07 | 68.28 ± 1.88 | 0.40 |
| 7 | 15 | 10 | 1.2 | 9.68 ± 0.33 | 51.88 ± 0.27 | 3.00 ± 0.00 | 4.54 ± 0.05 | 0.79 ± 0.01 | 13.67 ± 0.44 | 9.75 ± 0.22 | 1.77 ± 0.08 | 73.67 ± 5.28 | 0.65 |
| 8 | 25 | 10 | 1.2 | 10.48 ± 0.27 | 52.29 ± 0.27 | 2.67 ± 0.00 | 5.21 ± 0.37 | 1.42 ± 0.10 | 11.85 ± 0.35 | 8.65 ± 0.26 | 1.45 ± 0.05 | 64.22 ± 0.40 | 0.38 |
| 9 | 20 | 7.5 | 0.8 | 8.71 ± 0.17 | 52.43 ± 0.36 | 2.84 ± 0.05 | 4.08 ± 0.31 | 0.91 ± 0.07 | 12.57 ± 0.21 | 8.24 ± 0.74 | 2.09 ± 0.10 | 74.56 ± 5.09 | 0.58 |
| 10 | 20 | 12.5 | 0.8 | 11.19 ± 0.36 | 50.37 ± 0.36 | 2.78 ± 0.19 | 4.72 ± 0.18 | 0.64 ± 0.03 | 10.83 ± 0.48 | 6.50 ± 0.25 | 0.74 ± 0.05 | 65.78 ± 7.03 | 0.54 |
| 11 | 20 | 7.5 | 1.2 | 8.89 ± 0.21 | 49.87 ± 1.59 | 3.11 ± 0.19 | 5.25 ± 0.07 | 0.81 ± 0.02 | 12.60 ± 0.29 | 10.61 ± 0.57 | 0.67 ± 0.06 | 73.00 ± 4.67 | 0.64 |
| 12 | 20 | 12.5 | 1.2 | 11.48 ± 0.29 | 50.60 ± 0.35 | 3.11 ± 0.18 | 4.87 ± 0.10 | 0.90 ± 0.09 | 13.35 ± 0.46 | 9.24 ± 0.29 | 2.62 ± 0.01 | 68.73 ± 6.66 | 0.51 |
| 13 | 20 | 10 | 1 | 9.88 ± 0.15 | 47.03 ± 0.21 | 2.92 ± 0.17 | 4.91 ± 0.46 | 1.08 ± 0.06 | 15.66 ± 0.33 | 11.81 ± 0.30 | 1.14 ± 0.05 | 72.56 ± 6.25 | 0.66 |
| 14 | 20 | 10 | 1 | 9.99 ± 0.56 | 48.04 ± 0.26 | 2.89 ± 0.19 | 4.71 ± 0.14 | 1.14 ± 0.05 | 14.89 ± 0.95 | 11.41 ± 0.34 | 1.52 ± 0.01 | 71.56 ± 5.66 | 0.62 |
| 15 | 20 | 10 | 1 | 10.12 ± 0.51 | 47.67 ± 0.16 | 2.84 ± 0.19 | 4.73 ± 0.47 | 1.20 ± 0.04 | 15.73 ± 0.05 | 12.80 ± 0.73 | 1.26 ± 0.11 | 73.88 ± 4.32 | 0.71 |

[1]Values are means ($n = 3$) ± SD. DFC: dietary fiber content; OCT: optimized cooking time; CL: cooking loss; SE: sensory evaluation; S: synthetic evaluation index.

and NaCl (1.0 g) using a dough mixer for 10 min [13]. The dough was kneaded and rolled to form a 1.2 mm thick wrapper. The wrapper was stored at −20°C for a week and thawed at room temperature before analysis.

*2.6. Optimized Cooking Time (OCT) of Dumpling Wrapper.* OCT for the dumpling wrapper (diameter, 5 cm) was evaluated according to the method described by Wu et al. [20]. The cooked dumpling wrapper was placed on a transparent glass slide and cut along the diameter. The OCT was the time at which the white core of the dumpling wrapper was observed to disappear (checked every 20 s after 2 min cooking).

*2.7. Cooking Loss (CL) of Dumpling Wrapper.* The dumpling wrapper (diameter, 5 cm) was cooked in boiling water (500 mL) for the OCT. The cooking water was then collected and dried to a constant weight in an oven at 105°C. The residue was weighed and the CL was expressed as the percentage of the starting material (calculated by dry basis).

*2.8. Color of Boiled Dumpling Wrapper.* The color of the boiled dumpling wrappers was measured in triplicate using a colorimeter (LabScanXE, Hunter Lab, USA). The values of $L^*$ (lightness), $a^*$ (redness), and $b^*$ (yellowness) were recorded. The total color difference ($\Delta E$) was calculated according to Wang et al. [9] based on the following equation:

$$\Delta E = \sqrt{\left(L^* - L_0^*\right)^2 + \left(a^* - a_0^*\right)^2 + \left(b^* - b_0^*\right)^2}, \quad (2)$$

where $L_0^*$, $a_0^*$, and $b_0^*$ are the color parameters of boiled dumpling wrapper with wheat flour.

*2.9. Texture Properties of Boiled Dumpling Wrapper.* According to Li et al. [14], hardness, chewiness, and firmness are significantly correlated with the comprehensive sensory evaluation of the dumpling wrapper, which can be measured to express the texture properties. The hardness, chewiness, and firmness of the boiled dumpling wrapper were measured according to the method described by Li et al. [13]. Boiled dumpling wrapper (diameter, 5 cm) was placed in a texture analyzer (TA. XTPLUS, Stable MicroSystem, UK) to analyze the hardness and chewiness. The test parameters were as follows: pretest speed, 1.00 mm/s; test speed, 0.80 mm/s; posttest speed, 0.80 mm/s; target mode, strain; distance, 10.00 mm; strain, 70.00%; time, 3.00 s; trigger type, auto force; trigger force, 5.00 g; and trigger distance, 2.00 mm. Every treatment was measured six times, and the values were averaged.

Boiled dumpling wrapper ($7 \times 3\ cm^2$) was placed in the texture analyzer to analyze the firmness. The test parameters were as follows: test mode, compression; pretest speed, 1.00 mm/s; test speed, 0.80 mm/s; pretest speed, 10.00 mm/s; trigger mode, force; force, 1000.00 g; distance, 5.00 mm; strain, 100.00%; trigger force, 5.00 g; and trigger distance, 2.00 mm. Every treatment was measured six times and the values were averaged.

*2.10. Sensory Evaluation of Boiled Dumpling Wrapper.* The sensory qualities of boiled dumpling wrapper were assessed by ten trained panelists (five females and five males) who had sensory evaluation experiences of wheaten food. The panelists were trained to identify the specific sensory traits of dumplings, which was based on the official method of Chinese dumpling wrapper (SB/T 10138/93) (Chinese Ministry of Commerce 1993). The scoring system included appearance color (weighting factor, 10), brightness (10), transparency (10), resilience (15), stickiness (15), smoothness (10), resistance at boiling (15), and soup character (15). Six samples were tested by each panel and the dumpling wrapper made from pure wheat flour was set as the control, with scored appearance color of 8, brightness 8, transparency 8, resilience 12, stickiness 12, smoothness 8, resistance at boiling 12, and soup character 12, respectively.

*2.11. In-Vitro Starch Digestibility.* The in vitro starch digestion was measured according to the method of Souilah et al. [21]. Blend flour (40 mg) was dissolved in phosphate buffer solution (10 mL, 0.2 mol/L, pH 6.9) and $\alpha$-amylase (2 mL, 0.1 mg/mL, A3176, Sigma-Aldrich) was added. The sample was incubated at 37°C for 3 h in a shaking water bath. A 0.2 mL aliquot of the solution was taken at 20, 40, 60, 80, 90, 100, 120, 140, 160, and 180 min and heated immediately in a boiling water bath for 5 min to inactivate the enzymes. Sodium acetate buffer solution (0.6 mL, 0.4 mol/L, pH 4.75) and amyloglucosidase (8.3 $\mu$L, 300 U/mL, A-7095, Sigma) were then added. The mixture was incubated at 60°C for 45 min to hydrolyze the digested starch into glucose. The glucose content of the mixture was then measured using a glucose oxidase peroxidase kit (Sigma, USA). The starch content was calculated by multiplying the glucose content by 0.9.

Rapidly digestible starch (RDS; % digestible starch at 20 min), slowly digestible starch (SDS; % digestible starch at 120 min − % digestible starch at 20 min), and resistant starch (RS; 100% − % digestible starch at 120 min) percentage contents were obtained from the glucose concentration. The kinetics of starch hydrolysis were established according to the nonlinear model detailed by Goñi et al. [22].

$$C_t = C_\infty \times \left(1 - e^{-kt}\right), \quad (3)$$

where $C_t$ is the percentage of starch hydrolyzed at time $t$, $C_\infty$ is the equilibrium percentage of starch hydrolyzed after 180 min, $k$ is the kinetic rate constant, and $t$ is the digestion time. The goodness of fit between the experimental and evaluated data was evaluated using the correlation coefficient ($r$). The area under the hydrolysis curve (AUC) was calculated by the following equation:

$$\mathrm{AUC} = \frac{C_\infty \left(t_f - t_0\right) - C_\infty}{k\left(1 - e^{-k\left(t_f - t_0\right)}\right)}, \quad (4)$$

where $t_f = 180$ min and $t_0 = 0$ min [22]. The hydrolysis index (HI) was expressed as the ratio of the AUC of the sample to that of white bread. The glycemic indices (GI) of flours were estimated as follows: $GI_{C90} = 39.21 + 0.803 \times C_{90}$ ($r = 0.909$), where $C_{90}$ is the percentage of starch hydrolyzed at 90 min; and $GI_{HI} = 39.71 + 0.549 \times HI$ ($r = 0.894$) [22]. Consequently, the average predicted glycemic index ($GI_{avg}$) of flours was defined as follows:

$$GI_{avg} = \frac{(GI_{C90} + GI_{HI})}{2}. \quad (5)$$

*2.12. Statistical Analysis.* The data were statistically analyzed by means of a stepwise multiple regression using Design Expert 8.0. Significant effects of independent variables on each response were determined by analysis of variance (ANOVA), and $P < 0.05$ was considered to be statistically significant.

The experimental data were fitted to a second-order polynomial model as

$$y = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_{11}x_{12} + a_{22}x_{22} + a_{33}x_{32} + a_{12}x_1x_2 + a_{13}x_1x_3 + a_{23}x_2x_3 + \varepsilon, \quad (6)$$

where $y$ is the response function, $a_0, a_1, a_2, a_3, a_{11}, a_{22}, a_{33}, a_{12}, a_{13},$ and $a_{23}$ are coefficients, $x_1$ is the potato flour, $x_2$ is the okara flour, $x_3$ is the konjac flour, and $\varepsilon$ is the random error term.

A second-order polynomial model was fitted to study the relationship between the responses and the 3 factors (potato, okara, and konjac flours). The response surfaces were drawn by plotting $y$ as a function of two variables by keeping the third variable constant. The regression analysis of the responses was conducted by fitting linear and quadratic models as suitable in the case of the respective responses.

## 3. Results and Discussion

The experimental mean values of quality attributes of 15 experiments are shown in Table 1. Response variables included DFC and DPPH of blend flours and OCT, CL, hardness, chewiness, firmness, color, and SE of the boiled dumpling wrapper. None of the variables showed significant effects on DPPH and firmness, while DFC was significantly affected by all variables. The quadratic effect of the three variables (potato, konjac, and okara flours) was significant on OCT, CL, hardness, color, and SE, and second-order regression models were obtained, as reported below. The fit model and regression coefficients of the response variables are shown in Table 2. For those response variables analysis, insignificant factors ($P > 0.05$) were removed from the models to obtain significant regression equations without damaging the model hierarchy.

*3.1. Properties of Blend Flours.* In this study, the DFC and AA of blend flours were important for optimization. Dietary fiber is a plant material that plays an important role in many physiological processes and in the prevention of diseases of different origins [6]. The DFC of the blend flours ranged from 8.21% to 11.78%, which was much higher than that of wheat flour, mainly due to okara and konjac flours, which contain over 50% DFC. All independent variables exhibited significant linear effects on DFC, with the following regression equation:

$$DFC = 10.01 + 0.51x_1 + 1.26x_2 + 0.085x_3, \quad (7)$$

where $x_1$ is the potato flour, $x_2$ is the okara flour, and $x_3$ is the konjac flour.

According to equation (7), the higher potato, okara, and konjac flour contents contributed to the higher DFC of the blend flours, with okara flour having a larger DFC increasing effect than those of potato and konjac flours. The DFC of konjac flour was actually greater than that of okara flour [10], while the regression coefficient of konjac flour was much lower than that of okara flour, which was associated with the konjac flour content being much lower in the blend flours (0.80–1.20 g/100.00 g).

DPPH was selected to determine the AA of the blend flours for optimization. The DPPH scavenging activity of the blend flours ranged from 46.12% to 52.43% (Table 1). The minimum chewiness was obtained in the formulation containing 25.00% potato flour, 7.50% okara flour, and 1.00% konjac flour (for experimental run 2), with maximum chewiness obtained in the formulation containing 20.00% potato flour, 7.50% okara flour, and 0.80% konjac flour (for experimental run 9). The model $P$ value of 0.4381 (Table 2) implied that the model was not significant by ANOVA, with none of the independent variables having a significant effect on DPPH scavenging (Table 2), which indicated that the potato, okara, and konjac flour contents studied had no significant ($P > 0.05$) effect on the DPPH scavenging ability of the blend flours. However, the below study clarified that the addition of potato, okara, and konjac flours effectively increased the AA of blend flours (Table 3). The DPPH radical scavenging activity of the flours is attributed to phenolic compounds, flavones, bioactive peptides, and vitamins [23]. High contents of phenolic acids, anthocyanins, and carotenoids, which are closely associated with antioxidants, have been reported in potatoes [24]. According to Li et al. [7], flavones are the main antioxidants contributing to the AA of the okara flour. Extensive research has indicated that foods rich in antioxidants play an essential role in lowering the risk of many chronic diseases [5, 6]. Optimization to obtain a high AA is meaningful and useful and can be beneficial for consumer health.

*3.2. Cooking Qualities of Dumpling Wrapper.* According to Wu et al. [20], OCT and CL were measured to evaluate the cooking quality of the dumpling wrapper. For dumpling wrappers, a shorter OCT is associated with a better cooking quality. The OCT of dumpling wrapper varied between 2.50 and 3.11 min (Table 1). Okara flour had no significant effect on the OCT, while both potato and konjac flours did have significant effects ($P < 0.05$) on the OCT, with the following regression equation:

$$OCT = 2.88 - 0.10x_1 + 0.12x_3 - 0.22x_1^2, \quad (8)$$

where $x_1$ is the potato flour and $x_3$ is the konjac flour.

A higher potato flour content was observed to result in a shorter optimal cooking time. Potato flour is more easily

Table 2: ANOVA evaluation of response variables and prediction model coefficients.

| Response values source[1] | DFC | | DPPH | OCT | | CL | | Firmness | Hardness | | Chewiness | Color | | SE | | $S$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CE | $P$ value | $P$ value | CE | $P$ value | CE | $P$ value | $P$ value | CE | $P$ value | $P$ value | CE | $P$ value | CE | $P$ value | CE | $P$ value |
| Model | Linear | | Quadratic | Quadratic | | Linear | | Quadratic | Quadratic | | Quadratic | Quadratic | | Quadratic | | Quadratic | |
| Intercept | 10.01 | <0.0001 | 0.44 | 2.88 | 0.016 | 4.68 | 0.032 | 0.15 | 15.43 | 0.03 | 0.08 | 1.31 | 0.0034 | 72.67 | 0.0011 | 0.66 | 0.0077 |
| $x_1$ | 0.51 | <0.0001 | 1.00 | −0.10 | 0.013 | 0.40 | 0.013 | 0.14 | −1.08 | 0.02 | 0.12 | 0.36 | 0.0036 | −2.79 | 0.0006 | −0.12 | 0.0012 |
| $x_2$ | 1.26 | <0.0001 | 0.74 | 3 | 0.36 | | 0.17 | 0.46 | −0.81 | 0.04 | 0.03 | | 0.50 | −3.47 | 0.0002 | −0.075 | 0.010 |
| $x_3$ | 0.085 | 0.034 | 0.40 | 0.12 | 0.0084 | | 0.21 | 0.45 | | 0.29 | 0.20 | | 0.21 | | 0.89 | | 0.90 |
| $x_1x_2$ | | | 0.51 | | 0.35 | | | 0.46 | | 0.20 | 0.24 | | 0.39 | | 0.20 | | 0.45 |
| $x_1x_3$ | | | 0.50 | | 0.088 | | | 0.088 | | 0.88 | 0.57 | −0.43 | 0.0077 | −1.57 | 0.029 | | 0.77 |
| $x_2x_3$ | | | 0.51 | | 0.72 | | | 0.28 | | 0.21 | 0.88 | 0.83 | 0.0004 | | 0.082 | | 0.42 |
| $x_1^2$ | | | 0.79 | −0.22 | 0.0030 | | | 0.16 | −1.33 | 0.03 | 0.10 | 0.39 | 0.013 | −3.77 | 0.0009 | −0.15 | 0.0029 |
| $x_2^2$ | | | 0.77 | | 0.81 | | | 0.17 | −1.67 | 0.01 | 0.03 | 0.37 | 0.015 | −2.65 | 0.0045 | −0.10 | 0.014 |
| $x_3^2$ | | | 0.04 | | 0.085 | | | 0.05 | −1.42 | 0.02 | 0.06 | | 0.198 | | 0.40 | | 0.82 |
| $R^2$ | | 0.99 | 0.63 | | 0.94 | | 0.54 | 0.83 | | 0.92 | 0.87 | | 0.97 | | 0.98 | | 0.96 |
| Adjusted $R^2$ | | 0.99 | 0.12 | | 0.82 | | 0.41 | 0.51 | | 0.76 | 0.65 | | 0.91 | | 0.94 | | 0.87 |
| Lack of fit | | 0.75 | 0.040 | | 0.16 | | 0.066 | 0.10 | | 0.17 | 0.21 | | 0.51 | | 0.65 | | 0.46 |

[1]Independent variables: $x_1$, potato flour; $x_2$, okara flour; $x_3$, konjac flour. DFC, dietary fiber content; OCT, optimized cooking time; CL, cooking loss; SE, sensory evaluation; S, synthetic evaluation index; CE, Coefficient Estimate. Nonsignificant factors ($P > 0.05$) were removed.

Table 3: Comparison of the qualities of wheat flour (dumpling wrapper) and optimized flour (dumpling wrapper)[1].

| | DFC (%) | RP | DPPH (%) | OCT (min) | CL (%) | Hardness (N) | Chewiness (N·mm) | Firmness (N) | Color | SE | S |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WF | 2.14 ± 0.22[a] | 0.048 ± 0.00[a] | 32.09 ± 0.67[a] | 3.00 ± 0.00[b] | 4.15 ± 0.23[a] | 17.34 ± 0.68[b] | 11.09 ± 0.31[a] | 0.90 ± 0.03[a] | 0.00 ± 0.00[a] | 80.00 ± 1.00[b] | 0.68[a] |
| OF | 9.59 ± 0.30[b] | 0.063 ± 0.00[b] | 49.21 ± 1.03[b] | 2.78 ± 0.19[a] | 4.29 ± 0.07[b] | 15.63 ± 0.12[a] | 14.67 ± 0.37[b] | 0.95 ± 0.04[a] | 1.57 ± 0.11[b] | 73.72 ± 2.63[a] | 0.71[b] |

[1]Values are means ($n = 3$) ± SD. Means with different letters in a column are significantly different ($P < 0.05$). WF: wheat flour; OF: optimized flour; DFC: dietary fiber content; RP: reduce power; OCT: optimized cooking time; CL: cooking loss; SE: sensory evaluation; S: synthetic evaluation index.

gelatinized than wheat flour owing to its low gelatinization temperature and high water absorption, resulting in a shortened cooking time [12]. Konjac flour possesses a strong water holding capacity [10], inhibiting water diffusion in the dumpling wrapper during the cooking process and extending the OCT of the dumpling wrapper.

CL is an important quality attribute of dumpling wrappers that measures the solid loss of materials into the cooking water, which determines the ability of the dumpling wrapper to maintain structural integrity during cooking [25]. Among the three independent variables, only potato flour showed a significant linear effect ($P < 0.05$) on CL, with the following regression equation:

$$CL = 4.68 + 0.40x_1, \tag{9}$$

where $x_1$ is the potato flour.

The predicted model showed that CL increased with the increasing of potato flour. These results were in agreement with those of [15], who showed that the CL of noodles increased with increasing potato flour content. These authors also reported that the addition of potato flour destroyed the gluten network structure, exposing starch particles on the outside, which resulted in increased starch loss during cooking.

*3.3. Texture Properties of Boiled Dumpling Wrapper.* Hardness is the peak force measured during the first compression cycle (the first bite) and is measured in N. Hardness is the force required to compress the material by a given amount [5, 20]. The hardness of boiled dumpling wrapper varied between 10.51 and 15.73 N (Table 1). The minimum hardness was obtained in the formulation containing 25.00% potato flour, 12.50% okara flour, and 1.00% konjac flour (for experimental run 4), while the maximum hardness was obtained in the formulation containing 20.00% potato flour, 10.00% okara flour, and 1.00% konjac flour (for experimental run 15). All independent variables exhibited significant quadratic effects on hardness, with the following regression equation:

$$H = 15.43 - 1.08x_1 - 0.81x_2 - 1.33x_1^2 - 1.67x_2^2 - 1.42x_3^2, \tag{10}$$

where $x_1$ is the potato flour, $x_2$ is the okara flour, and $x_3$ is the konjac flour.

The coefficient estimation of dumpling wrapper hardness showed that the potato, okara, and konjac flour contents had a negative effect on the hardness of the boiled dumpling wrapper. Wheat flour contains many gluten proteins, which ensure that the dumpling wrapper has good hardness and springiness [20]. In contrast, the potato, okara, and konjac flours contain no gluten protein, resulting in a decreasing in hardness due to weakening of the gluten network structure.

Chewiness is the product of hardness, cohesiveness, and springiness and is measured in N·mm. The chewiness of the boiled dumpling wrappers varied from 6.50 to 12.80 N·mm (Table 1). The formulation containing 20.00% potato flour, 12.50% okara flour, and 0.80% konjac flour (for experimental run 10) showed the minimum chewiness, while the maximum chewiness was obtained in the formulation containing 20.00% potato flour, 10.00% okara flour, and 1.00% konjac flour (for experimental run 15). The model $P$ value of 0.0751 (Table 2) implied that the model was not significant by ANOVA, with none of the experimental variables showing a significant effect on the chewiness of the dumpling wrapper. Li et al. [14] reported that the chewiness was positively correlated with the comprehensive sensory evaluation of the dumpling wrapper. As shown in Table 3, the chewiness of the optimized flour dumpling wrapper was higher than that of the wheat flour dumpling wrapper, with values of 14.67 and 11.09 N·mm, respectively.

The firmness of boiled dumpling wrapper varied between 0.64 and 1.31 N (Table 1). The minimum chewiness was obtained in the formulation containing 20.00% potato flour, 12.50% okara flour, and 0.80% konjac flour (for experimental run 10), while the maximum chewiness was obtained in the formulation containing 25.00% potato flour, 10.00% okara flour, and 1.20% konjac flour (for experimental run 8). The model $P$ value of 0.1496 (Table 2) implied that model was not significant by ANOVA, with none of the experimental variables showing significant ($P < 0.05$) effects on the dumpling wrapper firmness. Firmness is the force requited to cut the dumpling wrapper, expressed as the maximum shear force, and reflects the stability of the internal structure of the dumpling wrapper [13]. As shown in Table 3, the firmness of the optimized flour dumpling wrapper was slightly higher than that of the wheat flour dumpling wrapper, with values of 0.95 and 0.90 N, respectively, but the difference was not significant ($P > 0.05$).

*3.4. Color of Boiled Dumpling Wrapper.* Color quality is an important parameter that interferes with the flavor perception and can considerably affect food acceptability [26]. In this study, the total color difference ($\Delta E$) was used to characterize the color properties of the dumpling wrapper. Using ANOVA, all independent variables exhibited significant quadratic effects on $\Delta E$, with the following regression equation:

$$\Delta E = 1.31 + 0.36x_1 - 0.43x_1x_3 + 0.83x_2x_3 + 0.39x_1^2 + 0.38x_2^2, \quad (11)$$

where $x_1$ is the potato flour, $x_2$ is the okara flour, and $x_3$ is the konjac flour.

The $\Delta E$ values of 15 experimental runs were calculated by comparison with wheat flour dumpling wrappers, with lower $\Delta E$ values indicating better color quality. The $\Delta E$ values of the boiled dumpling wrapper varied between 0.67 and 2.62 (Table 1), indicating that the addition of potato, okara, and konjac flours slightly decreased the color quality of the dumpling wrapper. Ye et al. [27] reported a highly negative correlation between ash content and brightness ($L^*$ value) for dumpling wrappers ($r = -0.53$). The ash contents of the three additional flours were all higher than those of wheat flour. Our previous study showed that adding potato flour decreased the $L^*$ value of the blend flour, while okara flour increased the $b^*$ value of blend flour. Among the three independent variables, the most obvious color difference was observed with the konjac flour. However, the konjac flour content in the blend flours was in the range of 0.80–1.20 g/100.00 g, which resulted in no significant effect on the color of the dumpling wrapper.

*3.5. Sensory Evaluation (SE) of Boiled Dumpling Wrapper.* The SE scoring system included appearance color (weighting factor, 10), brightness (10), transparency (10), resilience (15), stickiness (15), smoothness (10), resistance at boiling (15), and soup character (15). In this study, the total score of all parameters was used as the response variable. Using ANOVA analysis, all independent variables exhibited significant quadratic effects on SE, with the following regression equation:

$$\text{SE} = 72.67 - 2.79x_1 - 3.47x_3 - 1.57x_1x_3 - 3.77x_1^2 - 2.65x_2^2, \quad (12)$$

where $x_1$ is the potato flour, $x_2$ is the okara flour, and $x_3$ is the konjac flour.

The SE scores for the dumpling wrappers are shown in Table 1 and varied from 60.94 to 74.56. The minimum sensory evaluation score was obtained in the formulation containing 25.00% potato flour, 12.50% okara flour, and 1.00% konjac flour (for experimental run 4), while the maximum score was obtained in the formulation containing 20.00% potato flour, 12.50% okara flour, and 0.80% konjac flour (for experimental run 10). The coefficient estimation showed that all independent variables had a negative effect on the SE of dumpling wrappers. The SE score decreased with increasing potato, okara, and konjac flour contents. The ash contents of the three flours were far higher than those of wheat flour, which might weaken the sensory properties of the dumpling wrapper [27]. Meanwhile, although the DFC was also higher than that of wheat flour, which was beneficial to health, a high DFC could negatively affect the sensory properties of dumpling wrappers [7].

*3.6. Optimization of Blend Flours.* In this study, it was not appropriate to use all nine response variables to optimize the dumpling wrapper formulation because the response variables contributed differently to the quality of the dumpling wrappers. To evaluate the contributions of the response variables and evaluate the comprehensive performance of the dumpling wrapper, the synthetic evaluation index ($S$) and membership value were used [9]. The criteria for selecting the optimized formulation were based on higher values of DF, AA, hardness, chewiness, and SE, and lower values of OCT, CL, firmness, and $\Delta E$. The $M$ values of DF, AA, hardness, chewiness, and SE were calculated using equation (13), while those of OCT, CL, firmness, and $\Delta E$ were calculated using equation (14):

$$M = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}, \quad (13)$$

$$M = \frac{X_{\max} - X_i}{X_{\max} - X_{\min}}, \quad (14)$$

where $M$ is the membership value of response variable being analyzed, $X_i$ is the data value of the response variable being analyzed, $X_{\max}$ is the maximum value of the data column, and $X_{\min}$ is the minimum value of the data column.

Considering the efficiency of the process and the quality of dumpling wrapper, SE was set as the most important factor. Appearance gives consumers the first impression of the dumpling wrapper, while a high DFC is also attractive. Therefore, the color ($\Delta E$) and DFC were set as the second-most important factors. Using ANOVA, the responses of DPPH, firmness, and chewiness to the variables were not significant, and their weight coefficients were the lowest. The weight coefficients ($\lambda$) of DFC, AA, OCT, CL, firmness, hardness, chewiness, $\Delta E$, and SE were assigned as 0.15, 0.05, 0.10, 0.10, 0.05, 0.10, 0.05, 0.15, and 0.25, respectively. A synthetic evaluation index ($S$) was then calculated using the following equation [9]:

$$S_j = \sum_{i}^{9} \lambda_i M_{ij}, \quad (15)$$

where $S$ is the synthetic evaluation index, $M$ is the membership value, $i$ is the sequence number of the response variables according to the order of DF, AA, OCT, CL, firmness, hardness, chewiness, $\Delta E$, and SE, and $j$ is the number of experimental runs, ranging from 1 to 15.

The calculated $S$ values are shown in Table 1. The $S$ values varied from 0.21 to 0.71, with the minimum $S$ value obtained for the formulation containing 25.00% potato flour, 12.50% okara flour, and 1.00% konjac flour (for experimental run 4), and the maximum value obtained for the formulation containing 20.00% potato flour, 10.00% okara flour, and 1.00% konjac flour (for experimental run 15). Using ANOVA, after removing all the nonsignificant terms, the estimated regression coefficients of $S$ generated a quadratic equation:

$$S = 0.66 - 0.12x_1 - 0.075x_2 - 0.15x_1^2 - 0.10x_2^2, \quad (16)$$

where $x_1$ is the potato flour and $x_2$ is the okara flour.

As shown by the predicted model, the potato and okara flours had significant ($P < 0.05$) quadratic effects on the $S$ value. According to the analysis results of Design Expert 8.0 software (StatEase, Inc., Minneapolis, Minnesota), the identified optimal blend flour for achieving the maximum $S$ value was 17.59 g of potato flour, 8.67 g of okara flour, and 1.20 g of konjac flour per 100.00 g of blend flour, at which the predicted $S$ value was 0.73. Considering the practical applications, this optimization was adjusted to 17.50 g of potato flour, 8.50 g of okara flour, 1.20 g of konjac flour, and 72.80 g of wheat flour per 100.00 g of blend flour.

The DFC and AA of the blend flour, and OCT, CL, firmness, hardness, chewiness, $\Delta E$, and SE of the dumpling wrapper under the optimal conditions are shown in Table 3. According to equations (13) and (15), the actual value of $S$ was 0.71, which was very close to the predicted value of 0.73.

*3.7. Comparison of Wheat Flour (Dumpling Wrapper) and Optimized Flour (Dumpling Wrapper) Qualities.* The blend flour composed of wheat, potato, okara, and konjac flours was optimized using the response surface methodology and the synthetic evaluation method. The qualities of the wheat flour (dumpling wrapper) and optimized flour (dumpling wrapper) were compared to verify the practicality of optimized formulation. As shown in Table 3, the synthetic evaluation index value of the optimized flour was higher than that of wheat flour, with values of 0.71 and 0.68, respectively, which showed that the optimized flour had excellent practicality. Although there was not so obvious difference in the comprehensive performances of the optimized flour and wheat flour, the DFC and AA (DPPH and RP) of the optimized flour were significantly ($P < 0.05$) higher than those of wheat flour, with the DFC increasing more than fourfold to 9.59%. The optimized flour was more attractive to consumers in terms of health. Among all indicators, both optimized flour and wheat flour had their own advantages, but the optimized flour showed a better comprehensive performance than wheat flour. Furthermore, the optimized flour is significant because it improves the utilization of potato and okara flours. Chang [28] obtained an optimized formulation for frozen dumpling wrappers using an orthogonal experiment, which added 15% potato flour, 46% water, and 1.0% salt. Liu et al. [29] studied the effects of konjac flour and defatted okara flour on noodle quality and obtained an optimized formulation (okara flour, 8% and konjac flour, 0.5%) using an orthogonal experiment.

*3.8. In Vitro Kinetics of Starch Digestion and Modeling.* To further verify the practicality of optimized flour, the in vitro kinetics of starch digestion were measured. The starch hydrolysis curves of the two flours are shown in Figure 1, with both showing similar hydrolysis patterns, comprising an initial high hydrolysis rate followed by reduced hydrolysis rate in the later stages. Furthermore, wheat flour reached a plateau (maximum hydrolysis) after approximately 60 min,

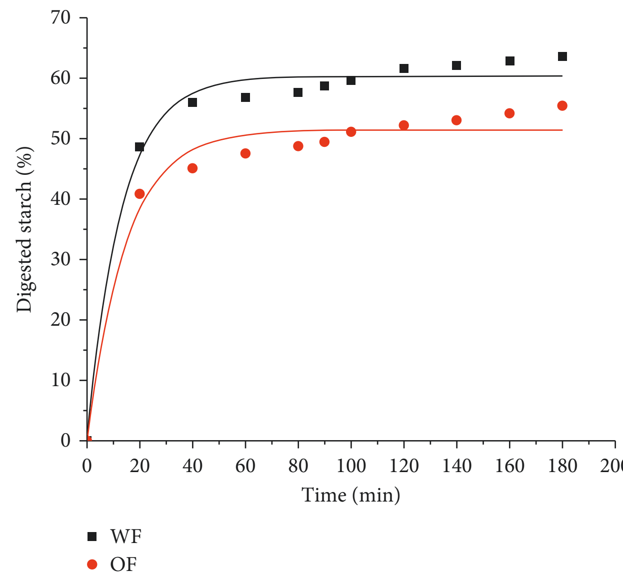


Figure 1: Hydrolysis curves of wheat flour and optimized flour. WF: wheat flour; OF: optimized flour.

with the optimized flour plateauing at the same time, implying that the addition of potato, okara, and konjac flours had no effect on the hydrolysis degree of wheat flour.

The nutritional properties, namely, the RDS, SDS, and RS contents of the two flours, after in vitro digestion, are shown in Table 4. The RDS of the optimized flour was lower than that of wheat flour, reaching 40.86% and 48.64%, respectively. RDS can be rapidly and thoroughly digested in the small intestine, which can cause a sudden increase in blood glucose level after ingestion and replenish energy quickly [30], which implied that flours with low RDS values decreased the rapidly available glucose values of foods. SDS is a desirable form of dietary starch that is slowly but completely digested in the gastrointestinal tract, thus prolonging glucose release and helping stabilize the glucose level [30, 31]. The SDS content of optimized flour was slightly lower than that of wheat flour, reaching 11.36% and 13.03%, respectively, both of which were similar to those reported by Jiang et al. [31] for different Dioscorea cultivars, which ranged between 7.00% and 19.87%. RS is beneficial to human health because it contributes to lowering cholesterol, increasing mineral absorption, reducing the risk of type-2 diabetes, improving insulin sensitivity in diabetics, inhibiting gall stone formation, and preventing colon cancer [32]. As shown in Table 4, the RS of the optimized flour was higher than that of wheat flour, reaching 12.02% and 5.12%, respectively, both of which were high compared with the RS contents of sorghum flours [21] and rice cultivars [33].

The digestive and glycemic parameters derived from the kinetic model are summarized in Table 4, including estimated parameters $C_\infty$ and $k$, the correlation coefficient ($r$), the hydrolysis index (HI), and the estimated glycemic index (GI). The $r$ values were close to 1 (0.98 and 0.97), implying that the kinetic model accurately described the experimental data. Both HI and $C_{90}$ are regarded as good predictors of GI, which indicates the digestibility of starch in foods. As shown

Table 4: Digestibility and glycemic parameters of nonlinear kinetic model of wheat flour and optimized flour[1].

| | RDS (%) | SDS (%) | RS (%) | $C_\infty$ (%) | $k$ (min$^{-1}$) | $r$ | AUC | HI (%) | $C_{90}$ | $GI_{C90}$ | $GI_{HI}$ | $GI_{avg}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WF | 48.64 ± 0.72$^b$ | 13.03 ± 0.54$^a$ | 5.12 ± 0.62$^a$ | 60.43 | 0.08 | 0.98 | 10087.99 | 67.25 | 58.67 | 86.32 | 76.63 | 81.47 |
| OF | 40.86 ± 0.91$^a$ | 11.36 ± 0.47$^b$ | 12.02 ± 0.81$^b$ | 51.51 | 0.07 | 0.97 | 8520.26 | 56.86 | 49.45 | 78.92 | 70.93 | 74.93 |

[1]Values are means ($n$ = 3) ± SD. Means with different letters in a column are significantly different ($P < 0.05$). WF: wheat flour; OF: optimized flour; RDS: digestible starch at 20 min; SDS: digestible starch at 20–120 min of incubation; RS: resistant starch; $C_\infty$: equilibrium percentage of starch hydrolyzed after 180 min; $k$: kinetic constant; $r$: correlation coefficient; AUC: area under hydrolysis curve; HI: hydrolysis index; $C_{90}$: percentage of starch hydrolyzed at 90 min; $GI_{C90}$: glycemic index predicted by $C_{90}$; $GI_{HI}$: glycemic index predicted by HI; $GI_{avg}$: average predicted glycemic index.

in Table 4, the HI value of the optimized flour was lower than that of wheat flour, at 56.86% and 67.25%, respectively, while their average predicted glycemic indices ($GI_{avg}$, calculated as the mean of $GI_{C90}$ and $GI_{HI}$) were 74.93% and 81.47%, respectively. The DFC of the optimized flour was higher than that of wheat flour (Table 4), which led to lower HI and GI values because dietary fiber can inhibit carbohydrate absorption [34].

## 4. Conclusions

The results obtained in the present investigation suggest that the optimal dumpling wrapper was composed of 17.50% potato flour, 8.50% okara flour, and 1.20% konjac flour (w/w). Compared with wheat flour, the optimized flour had a higher synthetic evaluation index value of 0.71. It was concluded that the optimized flour showed better comprehensive qualities, especially regarding DFC and AA. Furthermore, the optimized flour had a lower SDR, HI, and GI, and higher RS. This optimization study provides baseline data for developing fiber-rich functional dumpling wrappers using potato and okara flours. Further work is needed to investigate quality changes in the optimized dumpling wrapper when stored at −20°C.

## Data Availability

The data used to support the findings of this study are included within the article.

## Additional Points

There is an increasing interest in the nutritional and health protecting properties of indigenous and underutilized food resources. Potato, okara, and konjac have abundant dietary fiber and high antioxidant activities. In this study, the incorporation of potato, okara, and konjac flours into dumpling wrappers not only enhances the bioactive and physical properties of dumpling for human health benefits but also increases their market value.

## Conflicts of Interest

All authors have no conflicts of interest to disclose.

## Authors' Contributions

Yongli Jiang carried out all of the experiments. Yongli Jiang and Yun Deng conceived the study, designed the experiments, performed data analyses, and interpreted findings supported by all authors. Yimeng Zhao helped with laboratory experiments. Yongli Jiang and Danfeng Wang collected test data and drafted the manuscript. Yimeng Zhao edited the final manuscript.

## Acknowledgments

This work was supported by the Shanghai Municipal Agricultural Commission (2016NY001).

## References

[1] J. S. Silva, C. Damiani, E. P. Silva et al., "Effect of marolo (*Annona crassiflora* Mart.) pulp flour addition in food bars," *Journal of Food Quality*, vol. 2018, Article ID 8639525, 12 pages, 2018.

[2] M. D. Staffolo, A. C. K. Sato, and R. L. Cunha, "Utilization of plant dietary fibers to reinforce low-calorie dairy dessert structure," *Food and Bioprocess Technology*, vol. 10, no. 5, pp. 914–925, 2017.

[3] O. O. Awolu, R. O. Osemeke, and B. O. T. Ifesan, "Antioxidant, functional and rheological properties of optimized composite flour, consisting wheat and amaranth seed, brewers' spent grain and apple pomace," *Journal of Food Science and Technology*, vol. 53, no. 2, pp. 1151–1163, 2016.

[4] D. Romankiewicz, W. H. Hassoon, G. Cacak-Pietrzak et al., "The effect of chia seeds (*Salvia hispanica* L.) addition on quality and nutritional value of wheat bread," *Journal of Food Quality*, vol. 2017, Article ID 7352631, 7 pages, 2017.

[5] P. Singh, R. Singh, A. Jha, P. Rasane, and A. K. Gautam, "Optimization of a process for high fibre and high protein biscuit," *Journal of Food Science and Technology*, vol. 52, no. 3, pp. 1394–1403, 2015.

[6] J. Tian, J. Chen, X. Ye, and S. Chen, "Health benefits of the potato affected by domestic cooking: a review," *Food Chemistry*, vol. 202, pp. 165–175, 2016.

[7] B. Li, M. Qiao, and F. Lu, "Composition, nutrition, and utilization of okara (soybean residue)," *Food Reviews International*, vol. 28, no. 3, pp. 231–252, 2012.

[8] S. Huang, Y. He, Y. Zou, and Z. Liu, "Modification of insoluble dietary fibres in soya bean okara and their physicochemical properties," *International Journal of Food Science and Technology*, vol. 50, no. 12, pp. 2606–2613, 2016.

[9] G. Wang, Y. Deng, X. Xu et al., "Optimization of air jet impingement drying of okara using response surface methodology," *Food Control*, vol. 59, pp. 743–749, 2016.

[10] A. Akesowan, "Production and storage stability of formulated chicken nuggets using konjac flour and shiitake mushrooms," *Journal of Food Science and Technology*, vol. 53, no. 10, pp. 3661–3674, 2016.

[11] F. Jiménez-Colmenero, S. Cofradesa, A. M. Herreroa, F. Fernández-Martína, L. Rodríguez-Salas, and C. Ruiz-Capillas, "Konjac gel fat analogue for use in meat products:

comparison with pork fats," *Food Hydrocolloids*, vol. 26, no. 1, pp. 63–72, 2012.

[12] R. Ezekiel, N. Singh, V. R. Preedy, R. R. Watson, and V. B. Patel, "Use of potato flour in bread and flat bread," in *Flour and Breads and their Fortification in Health and Disease Prevention*, V. Preedy, R. Watson, and V. Patel, Eds., pp. 247–259, Elsevier Inc, Amsterdam, Netherlands, 2011.

[13] X. Li, Y. Lv, Y. Chen, and J. Chen, "A study on the relationship between rheological properties of wheat flour, gluten structure, and dumpling wrapper quality," *International Journal of Food Properties*, vol. 19, no. 7, pp. 1566–1582, 2012.

[14] X. Q. Li, J. J. Ge, Q. Xie, and H. Wang, "A Study on the relationship between sensory quality and texture quality of dumplings," *Journal of Henan University Technology*, vol. 33, no. 4, pp. 1–4, 2012, in Chinese.

[15] X. Liu, T. Mu, H. Sun, M. Zhang, J. Chen, and M. L. Fauconnier, "Comparative study of the nutritional quality of potato-wheat steamed and baked breads made with four potato flour cultivars," *International Journal of Food Sciences and Nutrition*, vol. 68, no. 2, pp. 167–178, 2016.

[16] U. Parvathy, J. Bindu, and C. G. Joshy, "Development and optimization of fish-fortified instant noodles using response surface methodology," *International Journal of Food Science and Technology*, vol. 52, no. 3, pp. 608–616, 2016.

[17] F. Zhu, R. Sakulnak, and S. Wang, "Effect of black tea on antioxidant, textural, and sensory properties of Chinese steamed bread," *Food Chemistry*, vol. 194, pp. 1217–1223, 2016.

[18] AOAC, Association of Official Analytical Chemists, *Official Methods of Analysis*, AOAC, Gaithersburg, MD, USA, 17th edition, 2008.

[19] R. Souilah, D. Djabali, B. Belhadi, H. Mokrane, N. Boudries, and B. Nadjemi, "In vitro starch digestion in sorghum flour from Algerian cultivars," *Food Science and Nutrition*, vol. 2, no. 3, pp. 251–259, 2014.

[20] G. Hu, Y. Zheng, Z. Liu, Y. Xiao, Y. Deng, and Y. Zhao, "Effects of high hydrostatic pressure, ultraviolet light-C, and far-infrared treatments on the digestibility, antioxidant and antihypertensive activity of alpha-casein," *Food Chemistry*, vol. 221, pp. 1860–1866, 2016.

[21] L. G. Wu, A. N. Wang, X. L. Li, and L. B. Qu, "Effect of extruded corn pericarp dietary fiber on dough rheology and dumpling wrapper quality," *Food Science and Technology International Tokyo*, vol. 20, no. 2, pp. 235–240, 2014.

[22] I. Goñi, A. Garcia-Alonso, and F. Saura-Calixto, "A starch hydrolysis procedure to estimate glycemic index," *Nutrition Research*, vol. 17, no. 3, pp. 427–437, 1997.

[23] Y. P. Zhu, J. F. Fan, Y. Q. Cheng, and L. T. Li, "Improvement of the antioxidant activity of Chinese traditional fermented okara (Meitauza) using *Bacillus subtilis* B2," *Food Control*, vol. 19, no. 7, pp. 654–661, 2008.

[24] G. Qiu, D. Wang, X. Song, Y. Deng, and Y. Zhao, "Degradation kinetics and antioxidant capacity of anthocyanins in air-impingement jet dried purple potato slices," *Food Research International*, vol. 105, pp. 121–128, 2018.

[25] Y. Kim, J. I. Kee, S. Lee, and S. H. Yoo, "Quality improvement of rice noodle restructured with rice protein isolate and transglutaminase," *Food Chemistry*, vol. 145, no. 4, pp. 409–416, 2014.

[26] Y. Zhang, Y. E. Yi-Li, J. J. Liu, Y.-G. Xiao, Q.-X. Sun, and Z.-H. He, "The relationship between Chinese raw dumpling quality and flour characteristics of Shandong winter wheat cultivars," *Agricultural Sciences in China*, vol. 10, no. 11, pp. 1792–1800, 2011.

[27] Y. L. Ye, Y. Zhang, and Z. H. He, "Relationship between wheat flour traits and dumpling sheet quality," *Journal of Triticeae Crops*, vol. 30, no. 2, pp. 280–285, 2010.

[28] Y. Chang, *Study on Effect of Potato Flour on the Quality of Frozen Dumplings*, Henan University of Technoogy, Zhengzhou, China, 2016, in Chinese.

[29] Y. Liu, L. Z. Liu, Y. U. Xiao-Hong, D. Zhang, and B. X. Dou, "Effect of potato flour on the quality of wheat flour and noodle," *Science and Technology of Food Industry*, vol. 37, no. 24, pp. 163–167, 2016, in Chinese.

[30] T. Huang, D. Zhou, Z. Jin, X. Xu, and H. Chen, "Effect of repeated heat-moisture treatments on digestibility, physicochemical and structural properties of sweet potato starch," *Food Hydrocolloids*, vol. 54, pp. 202–210, 2016.

[31] Q. Jiang, W. Gao, Y. Shi et al., "Physicochemical properties and in vitro digestion of starches from different dioscorea plants," *Food Hydrocolloids*, vol. 32, no. 2, pp. 432–439, 2013.

[32] C. O. Eleazu, K. C. Eleazu, and M. Iroaganachi, "In vitro starch digestibility, $\alpha$-amylase and $\alpha$-glucosidase inhibitory capacities of raw and processed forms of three varieties of Livingstone potato (*Plectranthus esculentus*)," *Innovative Food Science and Emerging Technologies*, vol. 37, pp. 37–43, 2016.

[33] Y. Deng, Y. Jin, Y. Luo et al., "Impact of continuous or cycle high hydrostatic pressure on the ultrastructure and digestibility of rice starch granules," *Journal of Cereal Science*, vol. 60, no. 2, pp. 302–310, 2016.

[34] K. S. Sandhu and S. T. Lim, "Digestibility of legume starches as influenced by their physical and structural properties," *Carbohydrate Polymers*, vol. 71, no. 2, pp. 245–252, 2008.