Journal of Food Research; Vol. 8, No. 4; 2019
ISSN 1927-0887 E-ISSN 1927-0895
Published by Canadian Center of Science and Education

Effect of Whole Purple Potato Flour on Dough Properties and Quality of Steamed Bread

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Received: May 20, 2019 Accepted: June 6, 2019 Online Published: July 2, 2019

doi:10.5539/jfr.v8n4p122 URL: https://doi.org/10.5539/jfr.v8n4p122

Abstract

WPPF was added into the wheat flour (WF) flour with different addition amount (0%~50%) to study the influence of whole purple potato flour (WPPF) on dough properties and quality of steamed bread. Result revealed that the WPPF addition significantly influenced the dough properties and quality of steamed bread. The water absorption, the maximum height of the gas release, total volume of CO_2 release and the hardness of steamed bread significantly increased with the increase of WPPF addition amount, while decreased the dough stability, the maximum height of dough, the gas holding capacity and the specific volume. Moreover, peak viscosity, final viscosity and setback value had a remarkable decrease when 10% WPPF added, but increased following the addition of WPPF. Considering the sensory evaluation, the steamed bread with 20% WPPF is acceptable. Appropriate addition amount of WPPF improves the nutrition value and variety of steamed bread and did not effect on the quality of the quality of dough and steamed bread.

Keywords: whole purple potato flour, pasting properties, fermentation properties, texture properties, sensory evaluation

1. Introduction

Purple potato is a cross-breed potato variety native to South America and introduced to China in recent years(Gan, Xin, & Yun, 2017).Purple potato has a high nutritional value due to the large amount of starch, dietary fiber, amino acids, minerals and vitamins. Each 100 grams of fresh purple potato contains about 11.0 mg of calcium, 1.2 mg of iron, 343.0 mg of potassium, 22.9 g of magnesium, 16.0 mg of vitamin C and 40 mganthocyanins(Qiu, Wang, Song, Deng, & Zhao, 2018), which can effectively compensate for the deficiencies of traditional staple foods(Gan et al., 2017).

Compared with other major crops potato has stronger adaptability to barren drought, severe climate and has higher production per units, it’s part for human consumption up to 85% (Lutaladio, Castaldi, & Lutaladio, 2009).In 2015, the Ministry of Agriculture of China proposed a strategy of potato staple food, and promoted the potato into a staple food such as steamed bread, noodles and synthetic rice. The potato will become another staple food other than rice, wheat and corn. Comparing with the consumption model of international China's potato is mainly used for fresh food, starch raw materials, and feed raw materials and so on. Increasing the consumption of potato in China can improve the fulfillment of the nutritional needs of the residents and promote the sustainable development of agriculture(Wang, Liu, & Zhao, 2016).

Lack of gluten in the respective products leads to weak dough structure and deterioration of crumb quality, therefore, potato food products are made from a mixture of potato flour and wheat flour, both to solve the problem of whole potato powder poor processing performance, and can remedy the nutritional limitations of potato flour.

The addition of whole purple potato flour changed the proportions of starches, protein and other components. Their presence influences water absorption, pasting properties and farinograph properties of the dough as well as texture and staling of the steamed bread, which allows the manufacture of products with strictly designed and controllable properties(Zhu, 2014).

In this research, the quality characteristics of steamed bread with high proportion of purple potato powder were investigated to provide a basis for further development of purple potato steamed bread.

2. Materials and Methods

2.1 Materials

Wheat flour (WF) was purchased from Yunhai Flour Factory, Zibo, CHN. Whole purple potato flour (WPPF) was obtained from LaolingXisen Potato Industry Group Co. LTD, Dezhou, CHN. Yeast was purchased from Angel Yeast Co., Ltd, Chifeng, CHN.

The flaky whole purple potato flour was crushed with an ultramicro grinder and sieved with 80 mesh sieve. WF and sieved whole potato flour were mixed at the ratio of 10:0, 9:1, 8:2, 7:3, 6:4 and 5:5, respectively, to get six kinds of blends.

2.2 Chemical Composition Analysis

The WPPF and WF were analyzed for moisture, ash, crude protein and crude starch according tothe AOAC methods (AOAC, 2007). The wet gluten content was determined according to GB/T 14608. All the valueswere measured in triplicates.

2.3 Farinograph Properties

Thefarinograph properties were investigated by Yucebas farinograph (Yucebasmakine, Izmir, TUR) according to the IS0 5530-I method.

2.4 Pasting Properties

The pasting properties were investigated by starch viscoanalyzer (DFY-1, Fangrui Instrument Co., Ltd, Shanghai, CHN). Sample (2 g) and distilled water (20 g) were mixed and then added into an aluminum canister. Then sample was heated to 95 ℃ at a rate of 2 ℃/min, held at 90 ℃ for 20 min and cooled to 50 ℃ at 2.25 ℃/min and then held for 10 min. The measurements werecarried out duplicate for each sample.

2.5 Rheofermentometer Rheological Measurements

Rheofermentometer rheological properties were investigated by RheofermentometerF4 (Chopin Technologies, Paris, FRA). Dough (315g, 1% yeast, water addition according table 2) was prepared and placed intothe instrumentat constant temperature of 30 ℃ for 3 h and 2 000 g was used as a restrain.

2.6 Steamed Bread Making Process

Dry yeast was dissolved with 36 ℃ distilled water and poured into 200 blended flour, surplus water (total water addition was determined by farinograph water absorption rate, table 2) was added to form dough.The dough fermented in a fermentation room (Brandone Equipment, Guangzhou, CHN) for 60 min at 36 ℃ and 80% relative humidity. Then, the dough was divided into 100 g dough piece, and each dough pieces were kneaded and shaped by hand. The second fermentation performed for 20 min at the same conditions as first fermentation.After fermentation, dough was steamed for 20 min and cooled for 60 min at room temperature.

2.7 Steamed Bread Quality Evaluation

2.7.1 Textural Profile Analysis (TPA) of Steamed Bread

The steamed bread was sliced into 20 mm pieces. TPA was measured using a TA.XT.plus Texture Analyser (Stable Micro Systems, Survey, UK).The measurement probe was used P/36R. The parameter settings below: compression degree was 60%; trigger force was auto-5 g; before testing speed was 2mm/s; testing speeding and post testing speed were 1mm/s; the interval time between two compression was 5s.

2.7.2 Determination of the Specific Volume of Steamed Bread

The specific volume of steamed bread (volume/mass) was determined using millet displacement for volume and electronic balance for mass.

2.7.3 Color

Color parameters were measured using a CM-3600A desktop color measurement instrument (Konica Minolta Investment Ltd., Shanghai, CHN). The equipment was standardized each time with white and black standards. Samples were scanned to determine lightness (L*), red-green (a*) and yellow-blue (b*) color components.

2.7.4 Sensory Evaluation

The sensory evaluation standard was according to the Gao et al.(2017). The sensory quality testing was performed by eight trained panelists in triplicate. All samples with randomized numbers were tested by panelists at the same time. The values of specific volume, appearance, color and luster, odor, viscosity, chewiness, elasticity and internal structure were scored by the panels. The best scores were20, 15, 10, 10, 10, 10, 10 and 15, respectively, and the total score was 100.

2.8 Statistical Analysis

Data were analyzedby averages, Duncan's t-test, ANOVA and least significant difference (LSD) test using SPSS Statistics 22 (IBM Corp., NY, USA). The least significant difference at the 5%probability level ($P < 0.05$) was calculated for eachparameter.

3 Results and Discussion

3.1 Proximate Composition from Two Flours

Table 1. Moisture, ash, crude starch, crude protein, crude ash and wet gluten contents of WPPF and WF(%)

	Moisture	Ash	Crude starch	Crude protein	Crude fat	Wet gluten
WF	12.59±0.23	0.53±0.01	70.56±0.21	12.86±1.25	0.87±0.01	34.14±0.16
WPPF	6.59±0.16	2.17±0.09	69.16±0.12	11.98±0.56	1.55±0.01	0

The basic composition of wheat flour and whole purple potato flour are presented in table1.The WF ash content was 0.53%,which indicated that the wheat flour used in this experiment had superior quality and high processing degree. The WPPF ash content was 2.17%, it is about four times as much as WF.This result showed that the whole purple potato powder is rich in minerals, such as iron, phosphorus, potassium, calcium, zinc and so on.

The protein content of the whole purple potato flour is slightly lower than that of wheat flour.But proteins are quite different in composition between WF and WPPF. WF protein mainly includes albumin (3%~5%), globulin (6%~10%), gliadin (40%~50%), glutenin (30%~40%) and other proteins (Osborne, 1907). WPPF protein mainly includes patain (about 40%), protease inhibitors (about 50%) and other macromolecular proteins (about 10%). Gliadin and glutenin are the main ingredient of gluten, lack of gliadin and glutenin resulted in gluten content of WPPF was no detectable and resulted in poor dough properties.

Studies have shown that the potato protein contains 8 kinds of essential amino acids (Bártová et al., 2015). In addition, the protein in wheat flour lacks lysine, can cause nutrition to unbalance. Therefore, from the nutritional value of protein, WPPT outbalance WF. Compared with WF, the mixed flour with WPPF had higher nutritional value.

3.2 Farinograph Properties

Table 2. Effect of WPPF on *farinograph* properties of wheat dough

Addition level (%)	Water absorption rate (%)	Development time (min)	Stability time / (min)	Degree of softening(FU)	Flour Quality Coef.
0	58.7	2.4	3.1	115	52
10	67.8	2.5	2.1	266	38
20	72.2	2.5	2.5	279	36
30	87.5	4.2	1.2	240	34
40	93.6	4.2	1.2	255	24
50	103.2	5.8	1.1	257	39

Table 2 showed the influence of WPPF on farinograph properties of WF. With WPPF addition, an increase in the water absorption was observed (from 58.7% to 103.2%), which might be due to the low moisture content and high damage starch content of WPPF. There also been a significant increase in development time (from 2.4 to 5.8 min), and the reason could be the high water absorption of WPPF results in the uneven water distribution in dough. Decrease in stability time (from 3.1 to 1.1 min) and degree of softening (from 115 to 257 FU) indicated the gluten strength of blends was weakened. The gluten protein was diluted with the increase of WPPF proportion. The interchain disulfide bond between the gluten polypeptide and the secondary bond is more likely to be broken. The ability to recombine to form the gluten network and the strength of the gluten skeleton were weakened, resulting in shortened dough stability time, increased degree of softening of the blends, and decreased four quality coefficients (Verwimp, Courtin, Delcour, & Hui, 2006).

3.3 Pasting Properties

Pasting behavior of different ratios blends determined using starch viscoanalyzer is presented in figure 1 and appendix A.The stir and heat resulted in the swelling of the starch and increases the viscosity at the initial stage

(S1), and then the blends system was homogenized and decreased the viscosity(Zhang, Mu, & Sun, 2018).

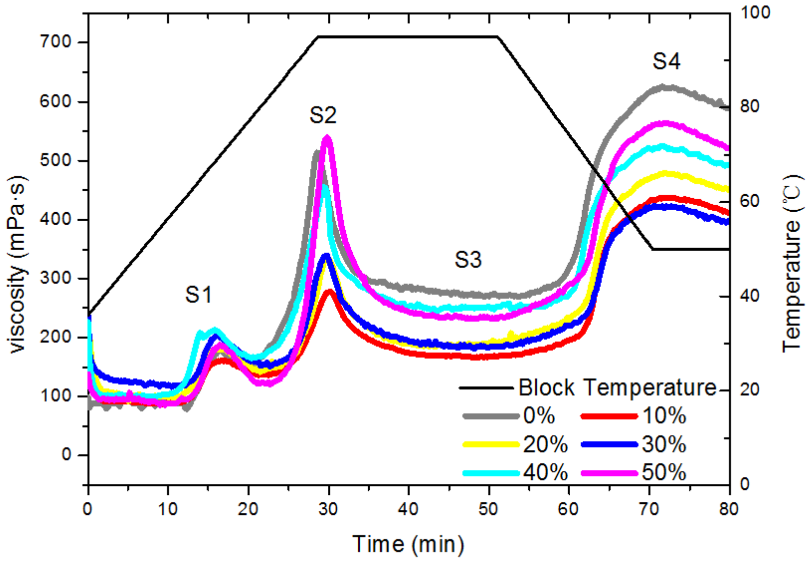

Figure 1. Pasting properties of the WPPF-WF blends systems

Note. WPPF, whole purple potato flour; WF, wheat flour. S1, the maximum dough consistency at the initial mixing stage; S2, the peak viscosity during the heating stage; S3, the minimum viscosity during the heating period; S5, the maximum viscosity obtained after cooling at 50 ℃

S2 is the peak viscosity (PV) of the WPPF-WF blends system during the heating stage. The peak PV of 0% was 527 mPa.s, whereas the 10%, 20%, 30%, 40% and 50% addition levels showed a PV of 278 mPa.s, 333.2 mPa.s, 339 mPa.s, 473.4 mPa.s, and 590.2 mPa.s, respectively. There was a rapid decrease of PV when 10% WPPF was added, and then heightened gradually with the ratio of WPPF increase. This might be due to the fact that the WPPF did not contain gluten protein, and the WPPF was added to the flour to play the role of diluting gluten. Moreover, since the starch in the WPPF had good adhesion property, the more stringy and cohesive textural properties of the potato starch made the blends more stable against stir (Swinkels, 1985), thereby increased the PV. The interaction of protein and starch made the WPPF addition affected the PV.

The PV of 0% came early (28.5 min) compared with WPPF addition blends (from 29.3 to 30.2min). The PV of the above blends system migrated to the high temperature direction because the WPPF starch competed with the wheat starch for water absorption, so that the gelatinization temperature of the mixed powder was increased. This is consistent with previous water absorption results in table 2.

The difference between S3 to S4 representation the setback value of WPPF-WF blends system. The setback value decreased with the increase of the WPPF addition, indicating that the addition of WPPF increased the anti-retrogradation performance of the blends. This may be mainly due to the strong water absorption of the whole potato powder, which limited the moisture available to the flour and hindered the expansion of wheat starch, which is not sufficient for the gelatinization of the system, resulting in the final viscosity, regenerative value (Zaidul, Yamauchi, Kim, Hashimoto, & Noda, 2007).

The mechanism of starch gelatinization was that the water molecules in the system move to the inside of the starch molecule and compete for hydrogen bonds(Lei, Tina, Sun, & Chun, 2008). When the energy of the water molecules was greater than the hydrogen bond energy between the starch molecules, the hydrogen bonds between the molecules and the molecules will break. So that the structure of the starch molecule was destroyed, fully stretched, and loose(Yang, 2009).

3.4 Fermentation Properties

Table 4. Effect of WPPF on fermentation rheological properties of wheat dough

Addition level / %	H_m/ mm	h/ mm	(Hm-h)/Hm	H'_m/ mm	V_T/ mm	V_R/ mm	V_C/ mm	V_r/V_t
0	25.5±0.13d	24.7±0.19e	3.1±0.01b	68.1±1.23a	1473±5.28a	1145±3.99a	328±10.25a	77.7±0.12e
10	19.1±0.15c	19.1±0.20d	0a	90.8±2.15b	1963±11.96b	1347±10.02b	616±11.52b	68.6±0.01d
20	15.9±0.12bc	15.9±0.08b	0a	109.3±0.58d	2463±11.27e	1498±24.95e	965±6.28e	60.8±0.50b
30	16.6±0.13b	16.6±0.06c	0a	113.9±1.23f	2572±15.68f	1530±4.52f	1042±14.76f	59.5±0.01a
40	10.5±0.05a	10.5±0.15a	0a	106.3±1.58c	2409±25.52d	1471±9.68d	939±9.58d	61.0 ±0.24c
50	9.6±0.02a	9.6±0.05a	0a	109.9±1.41e	2293±9.61c	1439±23.44c	855±8.46c	62.7±0.58c

Note. H_m, dough height at maximum development time; h, height of dough at the end of the test; H'_m, the maximum height of the gas release; V_T, total volume of CO_2 release; V_R, CO_2 volume still retained in the dough at the end of test; V_C, CO_2 volume that the dough has lost during test.Different letters in the same column are significantly different ($P < 0.05$).

The maximum dough height (H_m) and final dough height (h) were significantly lowered by the WPPF addition (table 3), which indicated dough development was significantly decreased. The reason might be speculated that WPPF restrained the extension of wheat dough during fermentation process (Penella, Collar, & Haros, 2008). There were a negative of dough development and stability with WPPF addition, which was also confirmed by the farinograph properties.

As the proportion of WPPF increased the maximum height of the gas release (H'_m), the total volume of CO_2 release (V_T), the CO_2 volume still retained in the dough (V_R) and the CO_2 volume that the dough lost (V_C) gradually increased, especially the addition of 30% WPPF was the most obvious. The reason might be that potato starch was made by high temperature, the structure of potato starch was changed, active sites of starch were emerged, the enzyme could easily contact the starch active sites, and then catalyze it into sugars which can be utilized by yeast. But as the WPPF increased further, the content of alpha-amylase decreased and affected the total volume of gas(Liu, Taihua, Sun, Zhang, & Chen, 2016). Despite the volume of gas produced in the WPPF dough was increased remarkably, the V_r/V_t was decreased which indicated gas holding capacity was weakened.

3.4 Quality of Steamed Bread

3.4.1 Texture Properties

Table 3. Effect of WPPF on texture properties of steamed bread

Addition level / %	hardness	adhesiveness	resilience	cohesion	springiness	chewiness
0	2973.01±349.18a	-15.24±1.35b	0.32±0.01cd	0.76±0.01ef	0.94±0.01abc	2119.66±223.54a
10	3447.87±411.97ab	-17.32±1.25b	0.41±0.01f	0.76±0.09f	0.94±0.01abc	2466.32±257.02ab
20	4166.75±451.65b	-18.42±1.47b	0.41±0.01f	0.75±0.015def	0.94±0.02abc	2933.94±271.93b
30	6360.66±495.23d	-34.45±1.38b	0.38±0.01cd	0.72±0.010c	0.95±0.04c	4401.68±319.66c
40	13881.32±575.19f	-28.00±1.37b	0.39±0.01cd	0.72±0.013bc	0.92±0.01ab	9197.94±481.88e
50	12125.78±521.12e	-73.42±5.54a	0.3614±0.01b	0.70±0.01b	0.92±0.01a	7825.14±488.88d

Different letters in the same column are significantly different ($P < 0.05$).

The effect of the amount of purple potato powder added on the texture of steamed bread was shown in Table 3. It can be seen from Table 3 that the total trend of the hardness of the steamed bread is increased with the increase of the total amount of purple potato powder. When the added amount was less than 30%, the hardness increased slowly; when the added amount reached 30%, the hardness increased greatly; while the added amount ranges from 30% to 50%, the hardness of the steamed bread did not change much. The resilience of the steamed bread was gradually increased and the structure of the steamed bread was firmed. The compression required a large force, and the force released during the recovery process was also large; the springiness and cohesiveness were gradually reduced, and the chewiness was directly related to the hardness, and the increase was obvious. Since the whole purple potato powder did not contain gluten protein, the whole purple potato powder was added to the flour to dilute the gluten protein, resulting in poor formation of the gluten network or partial tearing, the dough collapses, and the structure becomes compact. This also led to a decline in the cohesiveness of the steamed bread, which may be due to insufficient coverage of the starch molecules by the gluten network(Marston, Khouryieh, & Aramouni, 2016).

3.4.2 Specific Volume

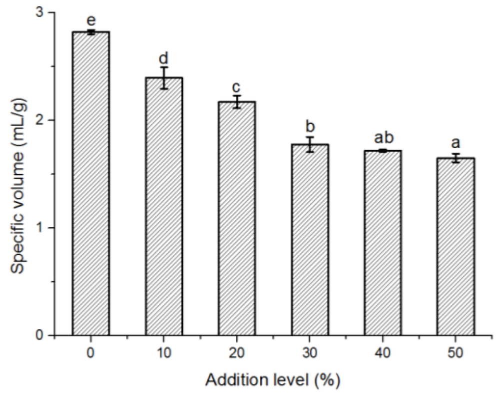

Figure 2. Effect of potato granule addition on specific volume of steamed bread

It can be seen intuitively from figure 2 that the specific volume of the steamed bread gradually decreased with the increased of the WPPF addition level. When the addition level was less than 20%, the larger specific volume indicated that the addition of a small amount of WPPF did not have much influence on the specific volume of the steamed bread. When the total amount of purple potato powder was higher than 20%, the specific volume is reduced. For one thing, it can be seen at 3.4, the gas production capacity increased with WPPF addition, but more volume of CO_2 released, which made dough a worse gas holding capacity(Arendt, Ryan, & Bello, 2007). For another, it diluted and damaged the structureof gluten network, that’s why WPPF samples werewith slight collapse and smaller specific volume.

3.4.3 Color

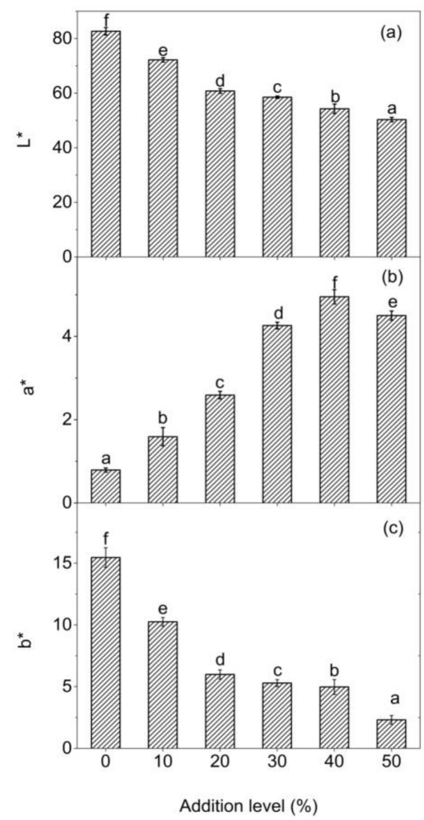

Figure 3. Color of the six kind of WPPF addition level steamed bread

Note. The L* value indicates brightness, 0 for black, 100 for white; (b) for a* value for red-green bias, positive for red, negative for green; (c) for b* for yellow-blue bias, positive for positive yellow, negative for blue.

Figure 3 showed the results of L*, a*, and b* evaluated of the steamed bread samples. Through the determination of desktop color measurement instrument, different ratio blends L*, a*and b* value, asshown in figure 3. Figure 3 (a) shows that the brightness of WF is above 80, with the increased of the WPPF, the L* value of became smaller and smaller, that is, the color becomes darker and darker. Figure 3 (b) shows that the a* value of WF is close to 0.5, hardly showing red color, while the a * value of 40% addition is about 4.5, showing obvious red color. As can be seen from figure 3 (c), there is a negative influence in the b* value of the WPPF. WF tends to be yellow, WPPF tends to be blue. Such changes could be largely attributed to the anthocyanins in WPPF (Zhu & Sun, 2019).

3.4.4 Sensory Evaluation

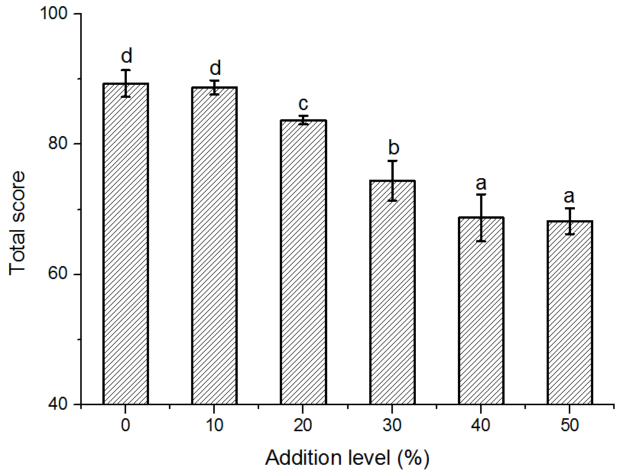

Figure 4. Effect of WPPF on sensory evaluationscore of steamed bread

Sensory evaluation of steamed bread is shown in figure 4 and appendix B. Total score was decreased with the WPPF added. The sensory evaluation dropped significantly when the WPPF addition exceeded 20%. Steamed bread increased the hardness with the WPPF added, thereby had hard texture and worse chewiness. In addition, the viscosity had a conspicuous decrease that had a strong impact on sensory evaluation. It probably due to the high damage starch content, the damaged starch was easy to absorb water and expand, and the volume was also increased. The space structure of the gluten was squeezed in space, destroying the gluten network structure. It was also had a negative effect on specific volume of steamed bread.

4. Conclusion

The WPPF addition increased the water absorption and development time, but decreased the dough stability. Peak viscosity, breakdown viscosity, final viscosity and setback value of 10% WPPF addition were found to be lower than thatof 0% addition. However, the values gradually increased by the WPPF addition from 10% to 50%. As the WPPF addition increased, there was a stronger gas production capacity, but the gas cannot beretained, and the gas holding capacity decreases.When the WPPF addition to more than 20%, specific volume, viscosity, chewiness, elasticity and internal structure decreased greatly, resulted in lower sensory value. The sensory value of steamed bread with 20% WPPF is acceptable.

Acknowledgments

This research was supported by the National Key Research and Development Project of China (2016YFD0401303).

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Appendix

Appendix A

Effect of WPPF on fermentation rheological properties of wheat dough

Addition level (%)	Peak viscosity (mPa s)	Trough (mPa s)	Break down (mPa s)	Final viscosity (mPa s)	Setback value (mPa s)	Peak time (min)
0	514.1	269.0	245.1	624.8	355.8	25.9
10	278.5	167.0	111.5	437.8	270.8	30.0
20	334.2	187.2	147	479.5	292.3	29.8
30	338.9	181.0	157.9	423.6	242.6	30.0
40	455.6	247.0	208.6	525.7	278.7	29.4
50	540.0	234.6	305.4	563.01	328.41	29.8

Appendix B

Effect of WPPF on sensory evaluationscore of steamed bread

Addition level (%)	Specific volume	Appearance	Color and luster	Odor	Viscosity	Chewiness	Elasticity	Internal structure	Total score
0	20	14	8.7	8.2	8.9	8.4	8.5	12.9	89.3
10	20	12.5	9	8.2	8.8	8.5	8.9	12.9	88.7
20	19	11.8	8.2	8.7	8.1	8.2	8.1	11.5	83.8
30	15	11.3	8.3	7.9	6.6	7.7	7.3	10.3	74.4
40	14	11.2	7.6	7.4	6.1	7.0	6.8	8.8	68.7
50	13	11.4	8.9	7.3	5.8	7.0	6.1	8.7	68.2