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Test conditions of texture profile analysis for frozen dough

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ORIGINAL ARTICLE

Abstract

Wheat flour is very important for making frozen dough. This paper firstly conducted an analysis of the basic properties of six varieties of wheat flour from different places and found that the variety BDHhgwf is most suitable to make frozen dough. Texture profile analysis (TPA) has been implemented in the dough-based food industry, and the properties of frozen dough were firstly investigated in this study. The results showed during TPA determination process of frozen dough, the variation of test parameters have an influence on the final result to some extent. The use of TPA in assessing the properties of frozen dough is presented. The recommended test conditions are: pre-test speed 3.0 mm/s, test speed (TS) 1.0 mm/s, posttest speed 1.0 mm/s, and compression ratio (CR) 50%. In a word, in this test method, the variation coefficient of dough was smaller and the dough was destroyed less by the texture analyzer and can truly reflect the texture of frozen dough.

Keywords: frozen dough; test conditions; texture profile analysis; wheat flour

Introduction

The principle of texture analyzer is mimicking what occurs inside the mouth and obtaining a force-time curve through two sample compression cycles, meant to identify some texture properties of food (Shin and Choi, 2021). Test action of texture analyzer mainly includes compression, TPA (texture profile analysis), puncture and penetration, cutting and shearing, fracture and bending, extrusion forward and backward, tension, and adhesion. TPA was developed about 48 years ago, and is the most commonly used imitative method, which utilizes a two-cycle uniaxial compression test for characterization of texture features, including hardness, cohesiveness, brittleness, gumminess, adhesiveness, chewiness, and elasticity according to the previous report (Cakir, 2011). In the process of food texture evaluation, compared with human sensory evaluation, TPA can obtain more intuitionistic and quantifiable parameters (Liu *et al.*, 2019). According to Figure 1, from 2000 to 2021, there have been extensive researches conducted on the use of TPA to measure textural properties of food products via Science Direct, mainly including fruits, meat, grain, and milk (Vidigal *et al.*, 2012). Therefore, TPA will be extensively used in the future and attract more professional researchers continuously in the food industry.

Setting the ideal parameters is not simple, but a complex task when using texture properties analyzer due to the various samples in many fields. At the same time, different TPA setting conditions are regarded as the main limiting factor for its use and as an official method of quality monitoring. In order to reduce the loss in the meat-based industry (Mittal *et al.*, 1992), the effects of various test conditions on the TPA parameters of beef products were assessed, and the recommended test conditions were: diameter to length (D/L) = 1.5, CR = 75%, and the rate of compression = 1–2 cm/min. On the other hand, Rivera

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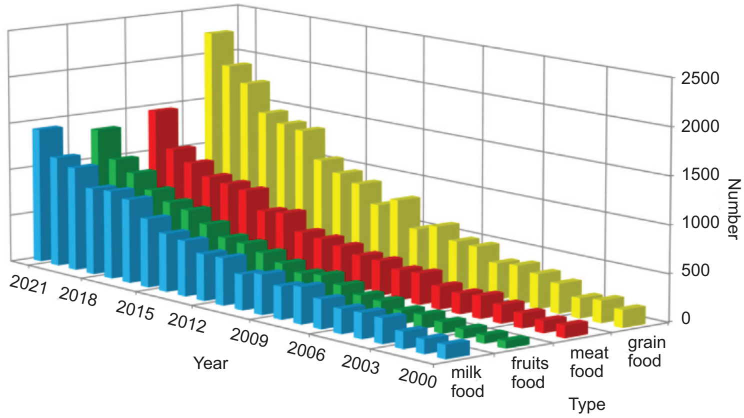

Figure 1. The application of TPA in four foods from 2000 to 2021. TPA, Texture profile analysis.

et al. (2021) determined that utilizing the combination of two strains (15 or 30%) and two durations between cycles (2 s and 10 s) as TPA operational settings can analyze the experimental data to a great extent Bernardo *et al.* (2021) obtained more representative results of fish products for the instrumental texture properties when setting the TPA parameters in the range of 60–75% (CR), 2–5 s holding time (HT), and 0.5–2.0 mm/s TS.

Above all, setting parameters is also a key issue to some extent with TPA in the baking and Chinese steamed bread (CSB) industry. As we all know, dough has an important influence on the food industry and can be used to make various flour products, which are more popular in western and eastern flavor culture. In eastern culture, CSB, which originated 2000 years ago in ancient China, is simply formulated by wheat flour, yeast, and water (Liu *et al.,* 2018). In China, the amount of wheat flour used in CSB accounts for more than 40% of the total wheat (Qian *et al.,* 2021). However, the urbanization greatly demands the industrialization of flour products. Comparing with the baking food, CSB has higher moisture content (more than 40%), which limits its further development (short shelf life) (Wang *et al.,* 2015). Therefore, it is necessary to solve the problem in frozen dough technology. On the other hand, in the western countries, bread is regarded as one of their most staple food items (Shu *et al.,* 2022). Frozen dough technology can effectively improve the quality and extend the shelf-life of products (Luo *et al.,* 2018b). At the same time, in order to meet the growth of these products' flexibility and consumption trends, frozen dough technology has gradually attracted the attention of the public and become the mainstream business of large-scale baking production (Omedi *et al.,* 2019). Therefore, frozen dough is one of the most important aspects in the food industry. Unfortunately, as far as our knowledge extends, there have been limited studies on the TPA conditions for frozen dough, and there is no unified test condition for TPA in the bakery industry in recent research. The objective of this paper was to find the best among the six wheat flours and evaluate the effects of various test conditions on TPA parameters for frozen dough. Furthermore, the paper aimed to ensure that the TPA measurements in reports should state clearly what conditions were used and provide a theoretical basis for establishing standardized measurement conditions which is necessary for the textural analysis of frozen dough in the baking and CSB industry.

Materials and Methods

Materials

Six purebred flours were from different brands. Shangyidao high gluten wheat flour (SYDhgwf) and wheat flour (SYDwf) were both produced by Shangyidao Science and Technology CO. Ltd. (Jiangsu, China). Beidahuang high gluten wheat flour (BDHhgwf) was produced by Beidahuang Fengwei Food CO. Ltd. (Heilongjiang, China). High winter wheat flour (HWwf) was produced by Lvhe Farm (Heilongjiang, China). Jinshuang wheat flour (JSwf) was produced by Bailemei Food CO. Ltd. (Heilongjiang, China). Russia wheat flours (Rwf) was produced by Xuetu Wheat flour CO. Ltd. (Russia).

Methods

Basic content of wheat flour

Moisture content was examined as Chinese GB/T5009.3-2010 for the determination of moisture content of food (direct drying method); protein content was examined as Chinese GB/T 5009.5-2010 for the determination of protein content of the food (Kjeldahl method); wet gluten was examined as Chinese GB/T5506.1-2008 for the determination of wet gluten of wheat flour (manual washing gluten method).

Extensogragh

The extensogragh parameters of wheat flour were measured by Extensograph (Brabender, Germany) according to the Chinese GB/T14615-2006 method. The dough extensibility (E), extensible area (A), extension resistance (R), the max extension resistance (R_m), extension ratio (R/E), and the max extension ratio (R_m/E) were obtained.

Farinograph

The farinograph was measured by a Brabender Farinograph®-E (Brabender OHG, Duisburg, Germany) according to AACC method 54-21 (AACC 2000). Three hundred grams of wheat flour blend (corrected to 14% moisture basis) was mixed in a kneading bowl (300 g). The water absorption (WA), development time (DT), stability time (ST), softening degree (SD), and farinograph quality number (FQN) of the mixtures were determined.

Frozen dough preparation

Flour samples were mixed to optimum dough by Brabender Farinograph®-E (Brabender OHG, Duisburg, Germany). The dough formula was: 100% of wheat flour, an amount of water (the water added to form optimum dough was calculated as the WA of flour obtained on the Farinograph, as shown in Figure 4), 1.5% dry yeast, and 1.5% salt (Kondakci *et al.,* 2015). Direct method was used to prepare dough; the yeast, water, and all ingredients were mixed in a laboratory dough mixer (Llano-B5, Guangzhou, China) for 8 min at a low speed (speed 3) and 2 min at medium speed (speed 5). The resulting dough (50 g) was molded, covered with polymer film, and stored at –36°C until the core temperature dropped to –18°C, then stored at –30°C for 7 days (Qingdao Haier Co. Ltd., Qingdao, China). The molded frozen dough was thawed in a fermentation cabinet (Beijing Tengwei Machine Co. Ltd., Beijing, China) at 30°C and 75% relative humidity until the core temperature was 10°C.

TPA in different speeds

TPA was conducted by texture analyzer (TA.XT2i, Stable Micro System, Surrey, UK). The results include hardness (g); fracturability (g); springiness, cohesiveness, and chewiness (g); and resilience that was defined by Pons and Fiszman (1996), as follows (Figure 2):

(1) Hardness is the maximum value at the first compression. Most foods have a hardness at the maximum deformation, but some foods do not have a peak force under the same conditions.
(2) Springiness indicates the ratio of a deformed sample to its height or volume before deformation after recovering the deformation force. It calculates the ratio between the measured height of the second and first flush (Length 2/Length 1).
(3) Cohesiveness is defined as the cohesiveness within the sample or the cohesiveness that holds the sample together. It calculates the ratio between the area of necessary work during the second and first impulse (Area 2/ Area 1).
(4) Adhesiveness indicates the force used to overcome the attraction between the two sample surfaces when the probe is in contact with the sample, which can measure the ratio of the area of negative peak to the area of penetration during the first thru-down stage (Area 3/ Area 4);
(5) Chewiness indicates the amount of energy required to chew a semi-solid sample into a swallowing state. It calculates the product gumminess × springiness (which is equivalent to hardness × cohesiveness × springiness).

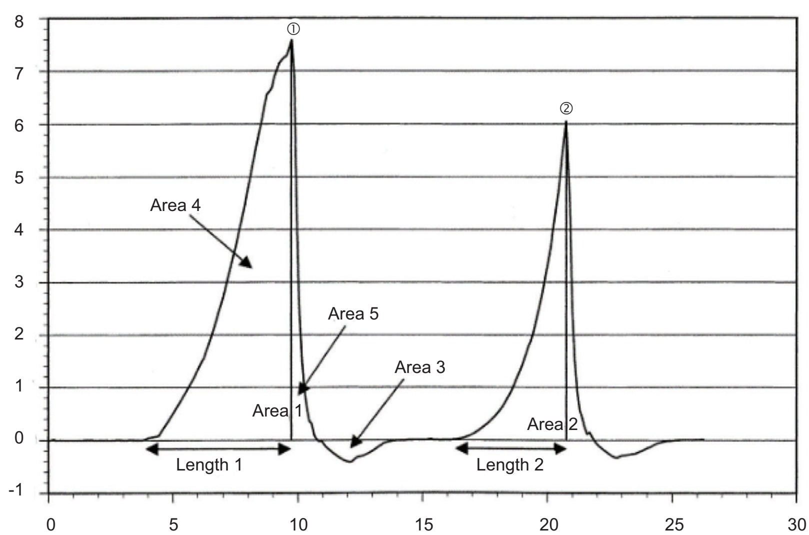

Figure 2. Typical force-by-time plot through two cycles of penetration of a longissimus thoracis rib steak to determine TPA parameters.

(6) Resilience indicates the extent to which a deformed sample can return to its original shape under the same conditions. It calculates the ratio of the area of the "recovery" stage in the first flushing to the area of the flushing stage in the downward pressing (Area 5/ Area 4).

Effect of pre-test speed on the test of TPA of frozen dough
The analysis was performed by a texturameter equipped with a 50 mm diameter aluminum cylinder. The parameters were determined from a two-cycle compression TPA force-time graph by the texture analyzer and the instrumental settings described by Wang *et al.* (2006). The test conditions were involved two consecutive cycles of 30–50% compression with 5s between cycles. It changed the pre-test speed (includes 1mm/s, 2 mm/s, 3 mm/s, 4 mm/s, and 5 mm/s).

Effect of pre-test speed on the test of TPA of frozen dough
It was performed according to the same method in 2.2.5.1 and only changed the TS. In brief, the pre-test speed was 1.0 mm/s; TS includes 0.5 mm/s, 1.0 mm/s, 1.5 mm/s, 2.0 mm/s, 2.5 mm/s, and 3.0 mm/s.

Effect of post-test speed on the test of TPA of frozen dough
It was performed according to the same method in 2.2.5.2 and only changed the post-test speed. In brief, pre-test speed was 3.0 mm/s, test-speed was 1.0 mm/s, and post-test speed includes 0.5 mm/s, 1.0 mm/s, 1.5 mm/s, and 2.0 mm/s.

Effect of CR on the test of TPA of frozen dough
It was performed according to the same methods in 2.2.5.3 and only changed the CR. In brief, pre-test speed was 3.0 mm/s, TS and posttest speed were both 1.0 mm/s, the CR includes 40, 45, 50, 55, and 60%.

Statistical analysis

All experimental data were presented as the mean of at least three readings. Analyses of results were done with one-way ANOVA and multiple comparisons (Fisher's least significant difference test) by SPSS software for Windows Release 17.0. P values of < 0.05 were significant.

Results and Discussion

Analyses of wheat flour

Basic components analysis of wheat flour
As indicated in Figure 3, there were some differences in moisture, protein, and wet gluten content of wheat flour. The moisture of wheat flour varied according to different storage conditions and sources. The moisture increased when stored with high humidity. Frozen dough can cause starch staling due to water loss during the freezing process (El-Hady *et al.,* 1996). At the same time, the water loss rate of dough increased with extension of the storage period (Gélinas *et al.,* 1996). Wheat flour with higher water content should be selected as far as possible, especially for making frozen dough. In Figure 3, BDHhgwf and JSwf had higher moisture (14.00%), which was fit to make frozen dough. Prolamin and glutenin in wheat flour are the material bases of dough extension and dough elasticity, respectively (Islam *et al.,* 2019). The wheat flour was divided into strong strength (11–14%), medium strength (9–11%), and weak strength (8–9%) flour according to protein content (Gao *et al.,* 2017). As shown in Figure 3, six varieties of wheat flour had more than 14% protein, with BDHhgwf having the highest protein content (18.80%), which all belong to strong strength flour. The rheology and baking properties of dough were studied after long-term frozen storage and repeated thawing with different strengths of flour and showed medium-strength and high-gluten flours were suitable for making frozen dough (Kondakci *et al.,* 2015). BDHhgwf was most suitable for making frozen dough due to its high protein content (18.80%) than that of other samples. In general, the wet gluten content of medium strength is in the range of 26–30%, while the strong strength flour has a higher content (30–40%) and the weak strength flour has a lower content (22–26%) (Naser *et al.,* 2020). The wet gluten content of SYDhgwf (36.45%), SYDwf (37.75%), and BDHhgwf (34.40%) were more than 30% and higher than the others. Through a comprehensive assessment of protein and wet gluten contents, BDHhgwf is more suitable for making frozen dough.

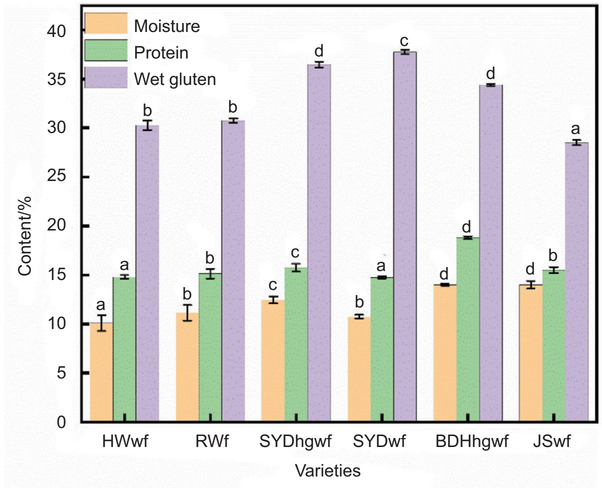

Figure 3. Basic components of different wheat flours (Mean values ± SD with different superscript letters for each attribute that differs significantly (P < 0.05)).

Farinograph analysis of wheat flour

In order to describe the basic rheology properties of wheat flour, the WA, DT, ST, SD, and FQN of the mixtures in farinograph experiment are shown in Figure 4. In general, the range of WA capacity of high gluten wheat flour was high (>62%) (Okuda *et al.,* 2016). BDHhgwf was the highest flour (65.4%) and HWwf was the lowest one (55.5%) in Figure 4A. This is mainly due to the difference in quantity and quality composition of wheat protein. The protein content and WA in wheat flour were positively correlated (Park and Baik 2004). At the same time, the bakeries desire increased relative WA of the flour as it produces more bread quantity.

DT was directly proportional to gluten strength, and ranged widely among the cultivars (Tian *et al.,* 2018). Long dough DT is a desirable feature for bread and stronger flours with higher protein content having a longer DT. The maximum DT was BDHhgwf (7.4 min) and SYDwf (7.4 min) and minimum DT was HWwf (1.7 min.) in Figure 4B. ST indicated the gluten strength flour, which was used to measure the dough's resistance to mechanical shear of the mixing blade (Huang *et al.,* 2016). Higher ST and lower SD mean stronger strength wheat flour. It is clear from Table 2 that the ST of BDHhgwf (7.8 min) was higher than SYDhgwf (6.4 min) and SYDwf (7.3 min). SD value indicated that the gluten had capacity of resistance to stir. The SD of HWwf was highest in these samples, which indicated that the gluten was not resistant to stir in this model. This may be because part of the gluten structure was damaged by temperature in the powder progress. The FNQ directly reflects the quality of flour (Luo *et al.,* 2018a). The SD of BDHhgwf was higher, which lowered the evaluation of the system and reduced its FNQ. Though the FNQ of SYDhgwf was the highest (106) as shown in Figure 4, lower WA (<62%) means that it is not fit for the baking industry. Moreover, during the freezing period of dough, the increase of WA rate in wheat flour could help delay starch staling caused by water loss that improved the quality of products (Barros *et al.,* 2018). In conclusion, BDHhgwf was more suitable to make frozen dough among these varieties.

Extensograph analysis of wheat flour

The dough extensibility (E), extensible area (A), extension resistance (R), the max extension resistance (R_m), extension ratio (R/E), and the max extension ratio (Rm/E) of the mixing flours containing different wheat flours are shown in Figure 5. The extensograph properties of all wheat flours had a significant difference ($P < 0.05$). Dough with great E is easy to elongate and not easy to break. Doughs with larger E were BDHhgwf (185 mm) and JSwf (205 mm). The A value was the necessary energy of the tensile dough and was a comprehensive reflection of the tensile characteristics of dough. The larger A indicated the stronger strength flour or dough (Tian *et al.,* 2018). It was clear that SYDhgwf and BDHhgwf had higher A values that were more than 185 cm^2 (Figure 5A). The R and E of the dough are the parameters used to determine the baking properties of flour (McCann *et al.,* 2016). R value is related to the gas-holding capacity in the fermentation process and CO_2 can be held in the dough only when R is not too low (Luo *et al.,* 2018a). At the same time, larger R leads to some problems including dough fermentation difficulty and a small volume in baking bread (Heitmann *et al.,* 2015). As can be seen from Figure 5A, Rwf and BDHhgwf were in the range of 350–500 BU and easier to make bread. The R_m/E indicated the dough elasticity and viscosity. According to the Figure 5B, SYDwf had the largest R_m/E that indicated greater elasticity and less viscosity and

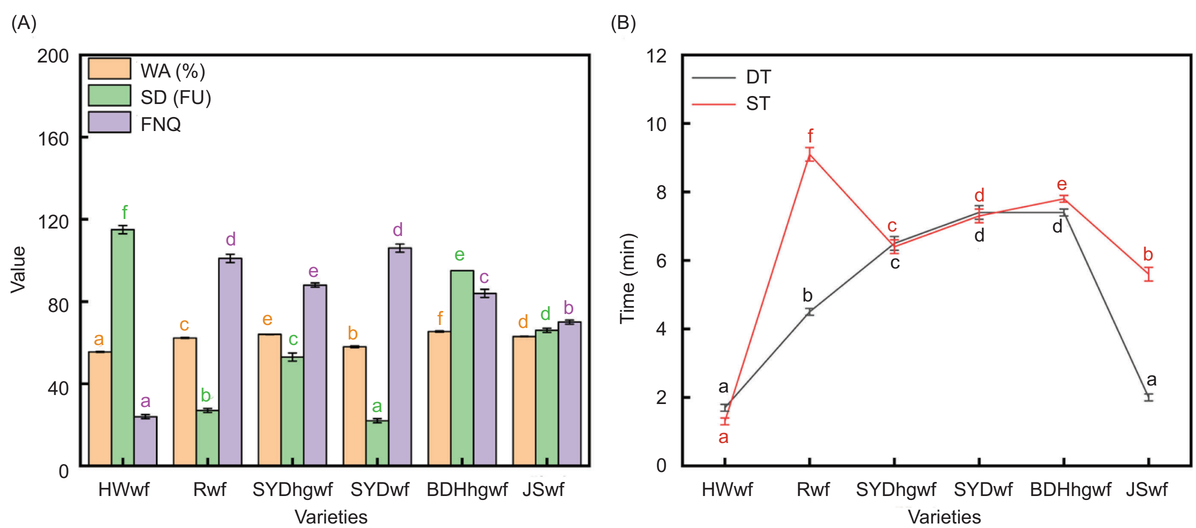

Figure 4. Farinograph parameters of different varieties of wheat flour (Mean values ± SD with different superscripts letter for each attribute differ significantly (P < 0.05)).

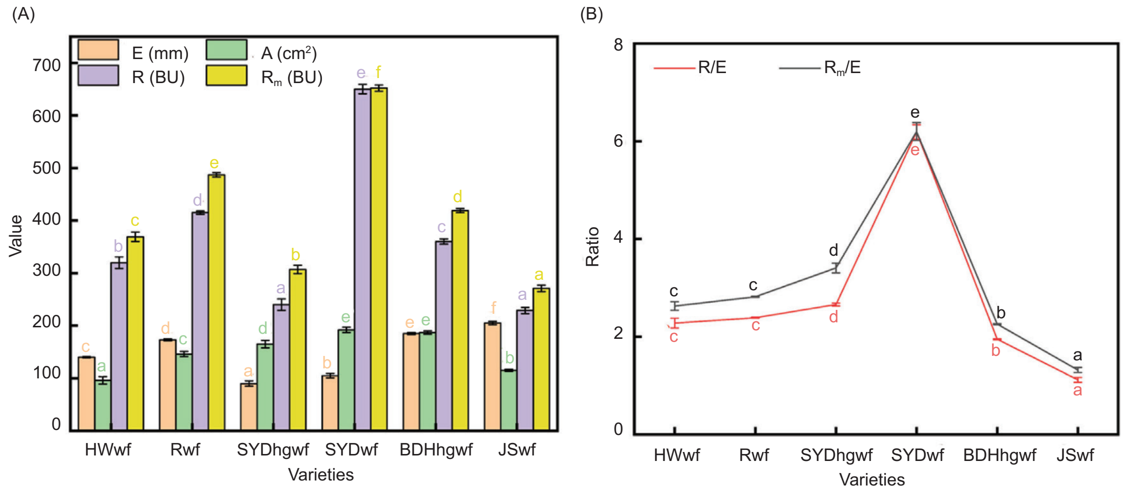

Figure 5. Extensograph parameters of dough from different varieties of wheat flour (Mean values ± SD with different superscript letters for each attribute differs significantly (P < 0.05)).

Table 1. Effect of pre-test speed on the test of TPA of frozen dough.

Speed (mm/s)	Hardness/g	Adhesiveness	Springiness	Cohesiveness	Chewiness/g	Resilience
1.0	1101.56 ± 57.42^{c}	-1286.51 ± 292.97^{c}	0.886 ± 0.03^{b}	0.71 ± 0.03^{b}	692.43 ± 40.41^{b}	0.158 ± 0.02^{a}
2.0	933.09 ± 148.27^{abc}	-2015.33 ± 292.14^{ab}	0.85 ± 0.03^{b}	0.68 ± 0.04^{ab}	552.40 ± 105.11^{b}	0.14 ± 0.02^{a}
3.0	1032.17 ± 53.53^{bc}	-2106.62 ± 186.22^{a}	0.85 ± 0.02^{b}	0.71 ± 0.01^{b}	630.12 ± 46.14^{b}	0.16 ± 0.01^{a}
4.0	800.50 ± 116.41^{ab}	-1500.44 ± 61.51^{bc}	0.85 ± 0.01^{b}	0.69 ± 0.04^{ab}	479.46 ± 109.59^{b}	0.14 ± 0.02^{a}
5.0	771.44 ± 45.15^{a}	−281.29 ± 14.88d	0.57 ± 0.05^{a}	0.61 ± 0.02^{a}	272.10 ± 38.38^{a}	0.13 ± 0.014^{a}

TPA, Texture profile analysis.

JSwf with the smallest R_m/E value had less elasticity and greater viscosity. Above all, BDHhgwf was the better flour in comparison with the others and more suitable to make frozen dough. Therefore, frozen dough was prepared by BDHhgwf in the following experiments.

Analysis of frozen dough

Effect of pre-test speed on the test of TPA of frozen dough

The effects of the crosshead speed can significantly affect TPA parameters of samples (Madieta *et al.,* 2011). In recent research (Kim *et al.,* 2021), sponge cake texture was tested at a pre-test speed of 2.0 mm/s and (Wang *et al.,* 2021) noodle texture was tested at 1.0 mm/s TPA. The effect of pre-test speed on frozen dough in TPA measurement is given in Table 1. The results showed that the texture properties of all samples with different pre-test speeds had a significant difference ($P < 0.05$). The adhesiveness, cohesiveness, and resilience which represent surface viscosity, internal polymerization, and recovery capacity, respectively, reached max value when pre-test speed was 3.0 mm/s. Then all parameters decreased along with pre-test speed increasing on the whole. When pre-test speed was more than 3.0 mm/s, the probe descended rapidly, causing the initial loss of moisture from the sample's surface, preventing the gluten from having sufficient time to fully relax. Therefore, the hardness, adhesiveness, springiness, cohesiveness, and resilience in later were lower. When the pre-test speed was less than 3.0 mm/s, the cohesiveness and resilience increased and as a consequence that part of water in the dough was absorbed by the flour; meanwhile, the internal gluten structure was regulated. In addition, the remaining water moved to the surface due to evaporation of surface water of dough, and the outward moving speed of water inside the dough was not completely consistent with that of external water evaporation. Especially at 3.0 mm/s, the difference was greatly significant and much water was on the surface, leading to the maximum adhesiveness of dough. Madieta *et al.,* (2011) thought of maximizing the mean values of all parameters and minimizing all the variation coefficients in the TPA experiment. According to Figure 6, the characteristic parameters had good reproducibility under 3.0 mm/s pre-test speed and showed that frozen dough could restore its original state and respond to the real test status. Therefore, the pre-test speed was reasonable to test the texture of frozen dough under 3.0 mm/s.

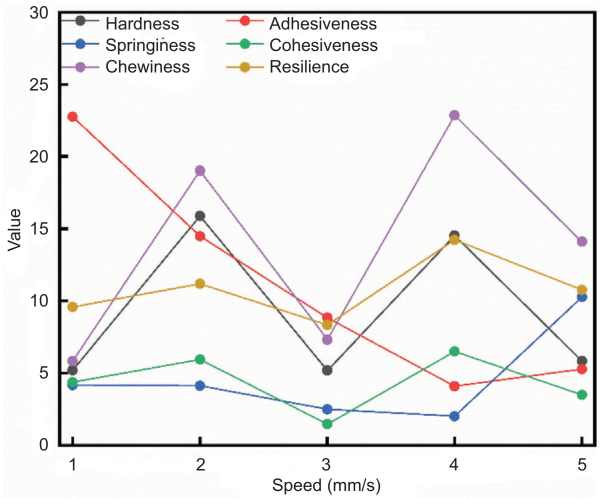

Figure 6. Results of pre-test speed on the variation coefficient of TPA in value. *Adhesiveness is absolute value in the figure. TPA, Texture profile analysis.

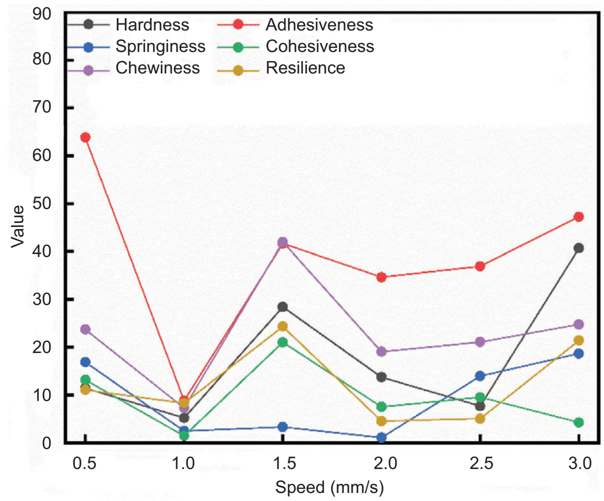

Figure 7. Results of test speed on the variation coefficient of TPA. *Adhesiveness is absolute value in the figure. TPA, Texture profile analysis.

Table 2. Effect of test speed on the test of TPA of frozen dough.

Speed (mm/s)	Hardness/g	Adhesiveness	Springiness	Cohesiveness	Chewiness/g	Resilience
0.5	656.08 ± 75.16^{a}	−758.00 ± 484.20^{b}	0.69 ± 0.11^{a}	0.59 ± 0.07^{a}	269.74 ± 64.20^{a}	0.15 ± 0.01^{a}
1.0	1032.17 ± 53.53^{a}	−2106.62 ± 186.22^{a}	0.85 ± 0.02^{a}	0.71 ± 0.01^{ab}	630.12 ± 46.14^{b}	0.16 ± 0.01^{a}
1.5	725.85 ± 206.30^{a}	−1368.95 ± 570.81^{ab}	0.86 ± 0.02^{a}	0.80 ± 0.61^{ab}	514.31 ± 216.14^{ab}	0.11 ± 0.03^{a}
2.0	835.26 ± 114.61^{a}	−958.96 ± 332.30^{b}	0.88 ± 0.01^{a}	0.78 ± 0.05^{ab}	578.49 ± 110.19^{ab}	0.14 ± 0.01^{a}
2.5	700.34 ± 53.85^{a}	−486.06 ± 179.52^{b}	0.74 ± 0.10^{a}	0.84 ± 0.08^{b}	421.72 ± 88.90^{ab}	0.13 ± 0.07^{a}
3.0	697.76 ± 283.20^{a}	−643.95 ± 304.00^{b}	0.80 ± 0.15^{a}	0.72 ± 0.03^{ab}	382.81 ± 94.73^{ab}	0.11 ± 0.02^{a}

TPA, Texture profile analysis.
Different superscripts within the same column indicate significant differences ($P < 0.05$).

Table 3. Effect of posttest speed on the test of TPA of frozen dough.

Speed (mm/s)	Hardness/g	Adhesiveness	Springiness	Cohesiveness	Chewiness/g	Resilience
0.5	686.05 ± 80.86^{ab}	−486.05 ± 254.95^{b}	0.69 ± 0.19^{a}	0.799 ± 0.01^{a}	374.43 ± 64.82^{ab}	0.125 ± 0.01^{a}
1.0	1032.17 ± 53.53^{c}	−2106.62 ± 186.22^{a}	0.85 ± 0.02^{a}	0.71 ± 0.01^{a}	630.12 ± 46.14^{b}	0.16 ± 0.01^{b}
1.5	791.76 ± 117.30^{abc}	−1322.22 ± 864.01^{ab}	0.65 ± 0.28^{a}	0.62 ± 0.15^{a}	325.33 ± 171.15^{ab}	0.12 ± 0.01^{a}
2.0	537.07 ± 117.00^{a}	−1963.77 ± 481.09^{ab}	0.70 ± 0.15^{a}	0.71 ± 0.12^{a}	280.20 ± 130.96^{a}	0.10 ± 0.02^{a}
2.5	851.17 ± 72.80^{bc}	−1356.88 ± 452.34^{ab}	0.73 ± 0.15^{a}	0.70 ± 0.02^{a}	436.19 ± 41.72^{ab}	0.12 ± 0.01^{a}

TPA, Texture profile analysis.
Different superscripts within the same column indicate significant differences ($P < 0.05$).

Effect of TS *on the test of* TPA *of frozen dough*

In the baking industry (Jiang *et al.,* 2019), bread texture was tested under 0.8 mm/s TS (Cui *et al.,* 2021; He *et al.,* 2020) or 1.0 mm/s TS. The effects of TS on frozen dough's physical characteristics in TPA measurement are given in Figure 6. In compression processing, as the TS speed increased, the probe spent less time on the sample, necessitating a greater capacity for compressive buffering. When the TS was 1.0 mm /s, the hardness, adhesiveness, chewiness, and resilience of the sample reached the maximum value, which means the gluten network structure of frozen dough began to be damaged any faster than that. However, springiness and cohesiveness decreased when TS was over 2.0 mm/s and 2.5 mm/s, respectively. When the TS was more than 2.5 mm/s, most sample structures were damaged and the second compression resistance was reduced. Considering the variation of each characteristic parameter, when the TS was 1.0 mm/s, the frozen dough had better internal structure and less damage. In addition, the variation coefficients of hardness, adhesiveness, cohesiveness, chewiness, and springiness were lesser, as shown in Figure 7. When the TS was 1.0 mm/s, the obtained characteristic parameters had good reproducibility and it was consistent with that reported by He *et al.,* (2020).

Effect of post-test speed on the test of TPA of frozen dough

In recent research, Zhu *et al.,* (2019) and Pan *et al.,* (2020) tested the texture of frozen dough under 0.8 mm/s posttest speed and Silvas-García *et al.,* (2014) tested its texture under 10.0 mm/s. Effect of posttest speed on frozen dough's physical characteristics in TPA measurement was given in Table 3. Hardness, adhesiveness, springiness, chewiness, and resilience reached the maximum value when posttest speed was 1.0 mm/s. The TS had the greatest influence on adhesiveness, springiness, and resilience, which depended on the recovery speed after compression and the posttest speed. When posttest speed is less than the sample recovery speed, adhesiveness, springiness, and resilience will reduce. While the post-test speed was close to recovery speed, it increased a lot. When the posttest speed was 1.0 mm/s, adhesiveness, springiness, and resilience reached the peak value. Furthermore, hardness and chewiness reached the maximum value also under 1.0 mm/s post-test speed, which was consistent with Wang. Wang and his colleagues believed that the chewiness was determined by the second compression, and the posttest speed should be the same as the TPA TS. Coefficient variation coefficient of TPA was shown in Figure 8, and characteristic parameters obtained good reproducibility under 1.0 mm/s posttest speed.

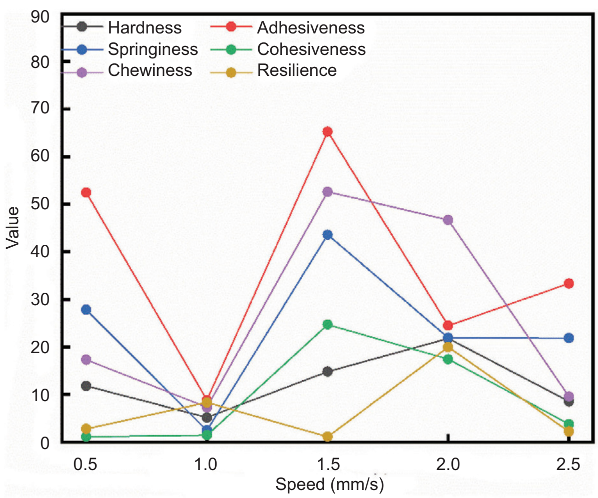

Figure 8. Results of post-test speed on the variation coefficient of TPA. *Adhesiveness is absolute value in the figure. TPA, Texture profile analysis.

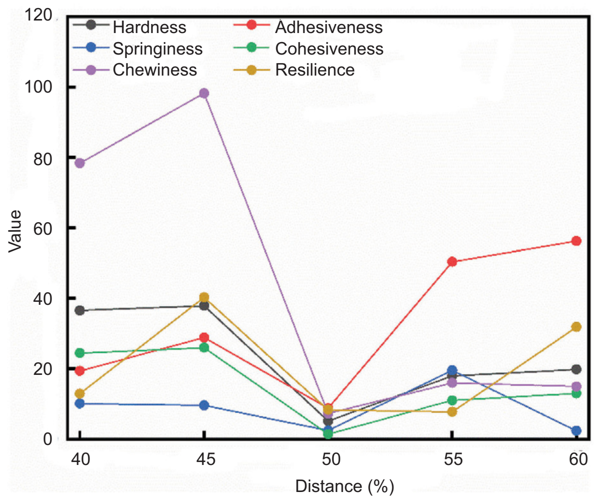

Figure 9. Results of CR on the variation coefficient of TPA. *Adhesiveness is absolute value in the figure. TPA, Texture profile analysis.

Table 4. Effect of CR on the test of TPA of frozen dough.

CR/%	Hardness/g	Adhesiveness	Springiness	Cohesiveness	Chewiness/g	Resilience
40	431.24 ± 157.76[a]	−1538.35 ± 233.90[a]	0.80 ± 0.08[a]	0.74 ± 0.18[a]	260.18 ± 59.14[a]	0.15 ± 0.02[a]
45	498.20 ± 188.77[a]	−1135.81 ± 328.29[a]	0.82 ± 0.07[a]	0.67 ± 0.16[a]	277.80 ± 43.12[a]	0.13 ± 0.04[a]
50	1032.17 ± 53.53[b]	−2106.62 ± 186.22[a]	0.85 ± 0.02[a]	0.71 ± 0.01[a]	630.12 ± 46.14[a]	0.16 ± 0.01[a]
55	1254.87 ± 226.006[b]	−1540.29 ± 624.99 [a]	0.79 ± 0.137[a]	0.66 ± 0.07[a]	583.63 ± 93.64[a]	0.13 ± 0.01[a]
60	1263.689 ± 250.885 [b]	−1661.50 ± 213.13[a]	0.858 ± 0.02[a]	0.77 ± 0.10[a]	823.83 ± 124.40[a]	0.13 ± 0.04[a]

TPA, Texture profile analysis.
Different superscripts within the same column indicate significant differences ($P < 0.05$).

Effect of CR on the test of TPA of frozen dough

CR also had an important role in the stability of the TPA test and can significantly affect the property of samples (Shin and Choi 2021). Kavuan *et al.,* (2020) manufactured chicken sausages using gelled emulsions as a beef fat substitute and performed TPA of the sausages which have a significant difference under 40% CR. The effect of CR on frozen dough in TPA measurement is given in Table 4. If the CR is too small or too large, the stability of measurement will be affected. When the CR is small, the distance between the height at which the instrument feels the minimum force and the maximum compression is not significant. The probe has a slight compression on the sample surface, which will serve to reduce the test accuracy and bigger errors. When CR is oversize, the sample structure will be largely damaged by probe compression. In the process of compression, the sample has poor stability and high TPA variation coefficient. With the increment of CR, change of adhesiveness is less, whereas hardness is gradually increased. Chewiness equals to hardness multiplied by springiness and cohesiveness. Cohesiveness and springiness had little change, therefore chewiness increased gradually with hardness. When the compression distance was greater than 50%, the hardness and chewiness increased a lot. There was no significant change in resilience, springiness, and cohesiveness which indicated that compression did less damage to the structure under the conditions we set. However, the increase in hardness and chewiness should be the consequence of acting force. When the CR was 50%, characteristic parameters obtained had good reproducibility in Figure 9. Therefore, 50% CR is a better condition for frozen dough. However, it does not consistent with the findings reported by (Jeong and Han 2019) for compression ratios below 40%, which could be attributed to differences in the sample variety.

Conclusion

Different varieties of wheat flour have different effects on the dough properties. In conclusions, BDHhgwf with higher gluten and protein content, showed that it is more suitable to make frozen dough among six kinds of wheat flour by extensogragh and farinograph experiments. During the TPA model, the variation of test parameters has an influence on the final result of frozen dough. The ideal test conditions are: the pre-test speed of 3.0 mm/s, TS of 1.0 mm/s, posttest speed of 1.0 mm/s, and CR of 50% for frozen dough. This study supplies a standard way for testing the frozen dough and can help researchers get more accurate and representative responses for instrumental texture of the frozen dough. At the same time, it can boost the flour process development of Heilongjiang and its application and the usage range of BDHhgwf in China.

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Credit Authorship Contribution Statement

Xinlai Dou was responsible for conceptualization; methodology; validation; formal analysis; investigation; data curation; writing of original draft, review, and AMP; and editing. Mingshou Lv,Xuyang Ren, and Yinyuan He was involved in conceptualization; validation; formal analysis; investigation; writing of review and AMP; and editing. Linlin Liu, Guang Zhang, Ying Sun was concerned with methodology; validation; writing of review and AMP; and editing. Na Zhang was responsible for conceptualization; writing of review and AMP; editing; and funding acquisition. Fenglian Chen, Chunhua Yang was involved in conceptualization; methodology; sourcing resources; writing of review and AMP; editing; supervision; project administration; and funding acquisition.

Conflict of Interest Statement

The authors declare that they do not have any conflict of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author upon reasonable request.

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