Test conditions of texture profile analysis for frozen dough

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Abstract

Wheat flour is more important for making frozen dough, this paper firstly conducted basic property of six wheat flour from different place and found BDHhgwf is more suitable to make frozen dough. Basic on it, texture profile analysis (TPA) has been put into applications in dough-made food industry, while the effects of the texture analysis parameters on 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 texture profile analysis (TPA) on frozen dough is addressed. The recommended test conditions are: pre-test speed 3.0 mm/s, test speed 1.0 mm/s, post-test speed 1.0 mm/s, and compression ratio 50%.

Introduction

The principle of texture analyzer is mimicking what occurs inside the mouth and obtaining a force–time curve through two sample compression cycles, meaningful to identify some texture properties of food (Shin and Choi 2021). Test action of texture analyzer mainly includes compression, TPA (texture profile analysis), puncture & penetration, cutting & shearing, fracture & bending, extrusion forward & back-ward, tension, and adhesion. TPA has 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, Cao et al. 2019). According to fig.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 food, meat food, grain food and milk food(Vidigal, Minim 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 varieties of 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-made industry, (Mittal, Nadulski et al. 1992)tested the effects of various test conditions on the TPA parameters of beef products, and showed that the recommended test conditions were: diameter to length (D/L) = 1.5, compression ratio (CR) = 75% and the rate of compression = 1-2 cm/min. On the other hand, (Rivera, Kerckhoffs et al. 2021) conducted that utilizing the combination of two strain (15% or 30%) and two duration between cycles (2 s and 10 s) as TPA operational settings can greatly analyze the experimental data. (Bernardo, do Rosario et al. 2021) obtained more representative results of fish product 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 test speed (TS).

Above all of studies, setting the parameters is also a key issue to some extent with TPA in the baking industry. As we all known, dough have an important influence on food industry and can be used to make different various flour products, which is more popular in western and eastern flavor culture. In eastern culture, Chinese steamed bread (CSB), originating 2000 years ago in ancient China, is simply formulated by wheat flour, yeast and water(Liu, Li et al. 2018). Especially in China, the amount of wheat flour used in CSB accounts for more than 40% of the total wheat(Qian, Gu 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, Tao et al. 2015). Therefore ,it is necessary to solve the problem in frozen dough technology. On the other hand, in the western countries, baking bread is regarded as one of the most staple food in their diet(Shu, Wei et al. 2022). Frozen dough technology can effectively improve the quality and extent the shelf-life of product (Luo, Sun et al. 2018). 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 has become the mainstream business of large-scale baking production(Omedi, Huang et al. 2019). Therefore, frozen dough is one of the most important fields in the food industry. Unfortunately, to the best of our knowledge, few studies on the conditions for the texture profile analysis of frozen dough and the test condition of TPA in bakery industry have no unified one in recent research. The objective of this paper was to find the better one in six wheat flour and evaluate the effects of various test conditions on TPA parameters for frozen dough. Furthermore, the paper aims to TPA measurements in reports should be stated 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 industry.

Materials And Methods

2.1 Materials

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

2.2 Methods

2.2.1 Basic content of wheat flour

Moisture content were examined as Chinese GB/T5009.3-2010 for Determination of Moisture Content of Food (Direct drying method); Protein content were examined as Chinese GB/T 5009.5–2010 for Determination of Protein Content of the Food (Kjeldahl method); Wet gluten were examined as Chinese GB/T5506.1-2008 for Determination of Wet Gluten of Wheat Flour (Manual washing gluten method).

2.2.2 Extensogragh

The extensogragh parameters of wheat flour were measured by Extensograph (Brabender,Germany) according to 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 ratioe (R_m/E) were obtained.

2.2.3 Farinograph

The farinograph was measured by a Brabender Farinograph®-E (Brabender OHG, Duisburg, Germany) according to AACC method 54 – 21 (Aacc 2000). 300 g 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.

2.2.4 Frozen Dough Preparation

Flour samples were mixed to optimum dough by Brabender Farinograph®-E (Brabender OHG, Duisburg, Germany). The dough was prepared according to the following formula (flour basis): 100% of wheat flour, 65.4% of water (The water added to form optimum dough was calculated as the water absorption of flour obtained on the farinograph). Mixing the flour and water until the dough was nearly formed (Kondakci, Zhang et al. 2015). 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 (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 up to 10 °C.

2.2.5 Texture profile analysis

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

(1) Hardness is the max value at the first compression. Most foods have a hardness at the max 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 that 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 that 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);

(6) Resilience indicates the extent to which a deformed sample can return to its original shape under the same conditions. It calculates that is 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).

The analysis was performed by a texturameter that equipped with a 50 mm diameter aluminum cylinder. The parameters were determined from a two-cycle compression TPA force-time graph generated by the texture analyser and the instrumental settings described by (Wang, Zhou et al. 2006). The test conditions involved two consecutive cycles of 30-50% compression with 5 s between cycles. The compression test was set as follows: Pre-test speed includes 1mm/s, 2 mm/s, 3 mm/s, 4 mm/s and 5 mm/s; Test speed 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; Post-test speed includes 0.5 mm/s, 1.0 mm/s, 1.5 mm/s and 2.0 mm/s; Distance includes 40%, 45%, 50%, 55% and 60%.

2.3 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

3.1 Analyses of Wheat flour

3.1.1 Basic components analysis of wheat flour

As indicated in Fig. 3 there were some differences among moisture, protein, 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 the water loss during the freezing process(El-Hady, El-Samahy et al. 1996). At the same time, the water loss rate of dough increased with the extension of storage period (Gélinas, Savoie et al. 1996). Wheat flour with higher water content should be selected as far as possible, especially for making frozen dough. Prolamin and glutenin in wheat flour are the material basis of dough extension and dough elasticity, respectively(Islam, Zhao 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, Koh et al. 2017). The rheology and baking properties of dough were studied after long-term frozen storage and repeated thawing with different strength flour and showed medium-strength and high-gluten flour were suitable for making frozen dough (Kondakci, Zhang et al. 2015). BDHhgwf was suitable for making frozen dough attributed to its protein content was higher 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 one (22%-26%) (Naser, Kasimie et al. 2020). The wet gluten content of SYDhgwf, SYDwf and BDHhgwf were higher than the other. Through a comprehensive assessment of protein and wet gluten contents, BDHhgwf is more suitable for making frozen dough.

3.1.2 Farinograph Analysis Of Wheat Flour

In order to describe the basic rheology properties of wheat flour, The water absorption (WA), development time (DT), stability time (ST), softening degree (SD) and farinograph quality number (FQN) of the mixtures in farinograph experiment were shown in fih.4. In general, the range of WA capacity of high gluten wheat flour was greatly high (62%)(Okuda, Tabara et al. 2016). BDHhgwf was the highest flour (65.4%) and HWwf was the lowest one (55.5%) in the Fig. 4. This 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, Cs et al. 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, Chen et al. 2018). Long dough DT is a desirable feature for bread and stronger flours with higher protein content have 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 the Table 2. ST indicated the gluten strength flour, which was used to measure the dough's resistance to mechanical shear of the mixing blade(Huang, Guo et al. 2016). Higher ST and lower SD means the stronger strength wheat flour. It is clear from the 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 the gluten was not resistance to stir in this model. This may due to that the part of the gluten structure was damaged by temperature in the powder progress. The FNQ directly reflects the quality of flour(Luo, Kou et al. 2018). The SD of BDHhgwf was higher, which lowered the evaluation of the system and reduced its FNQ. Though the FNQ of SYD hgwf was the highest one (106) in the Fig. 4, lower WA (< 62%) leads to that it is not fit in the baking industry. Moreover, during the freezing period of dough, the increase of WA rate in wheat flour could help delay the starch staling caused by water loss of its product that improved the quality of its products(Barros, Telis et al. 2018). In conclusion, BDHhgwf was more suitable to make frozen dough in these varieties.

3.1.3 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 (R_m/E) of the mixing flours containing different wheat flour were shown in Fig. 5. The extensograph properties of all wheat flour had a significant difference ($p < 0.05$). Dough with great E is easy to elongate and not easy to break. The 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, Chen et al. 2018). It is clear that SYDhgwf and BDHhgwf had higher A value that more than 185 cm^2 in the Fig. 5. The R and E of the dough are the parameters used to determine the baking properties of flour (Ekinci.2020). R value is related to the gas-holding capacity in the fermentation process and CO_2 can be hold in the dough only when R is not too low (Luo, Kou et al. 2018). At the same time, lager R leads to some problems including dough fermentation difficulty and a small volume in baking bread (Tian, 2011). As can be seen from Table 3 that Rwf and BDHhgwf were in the range 350–500 BU and more easier to make bread. The R_m/E indicated the dough elasticity and viscosity. According to the Table 3, the largest R_m/E is SYDwf that indicated greater elasticity and less viscosity and JSwf had less elasticity and greater viscosity with the smallest R_m/E value. Above all of it, BDHhgwf was the better flour in compare with the others and more suitable to make frozen dough. Therefore, the frozen dough was prepared by BDHhgwf in the following experiments.

3.2 Analyse of frozen dough

3.2.1 Effect of pro-test speed on the test of TPA of frozen dough

The effects of the crosshead speed can significantly affect TPA parameters of samples(Madieta, Symoneaux et al. 2011). In recent research(Kim, Ahn et al. 2021), sponge cake texture was tested at a pretest speed of 2.0 mm/s and (Wang, Guo et al. 2021)noodle texture was tested at 1.0 mm/s TPA. The effect of pro-test speed on frozen dough in TPA measurement was given in Table 1. The results showed the texture properties of all samples with different pro-test speed 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 pro-test speed was 3.0 mm/s. Then all parameters decreased along with pro-test speed increasing in the whole. When pro-test speed was more than 3.0 mm/s, the probe dropped quickly and the moisture on the sample surface was lost initially and gluten had no enough time to relax fully. Therefore, the hardness, adhesiveness, springiness, cohesiveness and resilience in later were lower. When the pro-test speed was less than 3.0 mm/s, the cohesiveness and resilience increased 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 other part of 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 significant greatly and much water was on the surface which lead to the maximum adhesiveness of dough. (Madieta, Symoneaux et al. 2011) thought maximising the mean values of all parameters and minimising all the variation coefficients were proper in the TPA experiment. According to the Fig. 4, the characteristic parameters had good reproducibility under 3.0 mm/s pro-test speed and showed frozen dough could restore its original state and respond to the real test status. Therefore, the pro-test speed was reasonable to test the texture of frozen dough under 3.0 mm/s.

Table 1
Effect of pro-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 ± 14.88^{d}	0.57 ± 0.05^{a}	0.61 ± 0.02^{a}	272.10 ± 38.38^{a}	0.13 ± 0.014^{a}

3.2.2 Effect of test speed on the test of TPA of frozen dough

In baking industry,.(Jiang, Zhao et al. 2019) bread texture was tested under 0.8 mm/s test speed (He, Guo et al. 2020, Cui, Liu et al. 2021) or 1.0 mm/s test speed. The effect of test speed on frozen dough physical characteristics in TPA measurement were given in table 6. In compression processing, as test speed increased probe had shorter time on the sample which had to buffered more compression capacity When the test speed was 1.0mm /s, the hardness, adhesiveness, chewiness and resilience of the sample reached the max value, which means the gluten network structure of frozen dough began to be damaged any faster than that. While springiness and cohesiveness decreased when test speed was over 2.0 mm/s and 2.5 mm/s respectively. When the test speed was more than 2.5 mm/s, most sample structure were damaged and the second compression resistance was reduced. Considering the variation of each characteristic parameter, when the test speed 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 smaller in Fig. 5. When the test speed was 1.0 mm/s, the obtained characteristic parameters had good reproducibility and it was consistent with (He, Guo et al. 2020)reported.

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}

Different superscripts within the same column indicate significant differences ($P < 0.05$)

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

In recent research, (Zhu, Zhang et al. 2019, Pan, Huang et al. 2020)tested the texture of frozen dough under 0.8 mm/s post-test speed and (Silvas-García, Ramírez-Wong et al. 2014)tested its texture under 10.0 mm/s. Effect of post-test speed on frozen dough physical characteristics in TPA measurement were given in Table 3. Hardness, adhesiveness, springiness, chewiness, resilience reached the max value when post-test speed was 1.0 mm/s. The test speed had the greatest influence on adhesiveness, springiness and resilience, which depended on the recovery speed after compression and the post-test speed. When post-test speed was less than sample recovery speed, adhesiveness, springiness and resilience will reduced. While the post-test speed is close to recovery speed, it will increase a lot. When the post-test speed was 1.0 mm/s, adhesiveness, springiness and resilience reached the peak value. Furthermore, hardness and chewiness reached max value also under 1.0 mm/s post-test speed which was consistent with Wang. Wang and his colleagues believed the chewiness was determined by the area of the second compression, and the post-test speed should be the same as the TPA test speed. Coefficient variation coefficient of TPA were showed in Fig. 5, and characteristic parameters obtained good reproducibility under 1.0 mm/s post-test speed.

Table 3
Effect of post-test 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 ± 0.01a
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}

Different superscripts within the same column indicate significant differences (P < 0.05).

3.2.4 Effect of compression ratio on the test of TPA of frozen dough

Compression ratio(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, Serdarolu 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 was 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 attribute to reduce the test accuracy and bigger error. 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 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 the most. 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 Fig. 9 Therefore, the 50% CR is the better condition for frozen dough. But it is not consistent with (Jeong and Han 2019) reported under 40% CR, it may due to the sample variety.

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

Different superscripts within the same column indicate significant differences (P < 0.05).

Conclusion

Different varieties of wheat flour exert different effects on the dough properties. In conclusions, BDHhgwf with higher gluten and protein showed that is more suitable to make frozen dough in six kind 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 is that : the pre-test speed 3.0 mm/s, test speed 1.0 mm/s, post-test speed 1.0 mm/s, compression ratio 50% for frozen dough. This study supplies a standard way for testing the frozen dough and can help researchers get more accurate and representative response for instrumental texture of the frozen dough. At the same time, it can boost the flour process development of Heilongjiang and application and usage range of BDHhgwf in China.

Declarations

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Credit authorship contribution statement

Xinlai Dou: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing.
Xuyang Ren, Yinyuan He: Conceptualization, Validation, Formal analysis, Investigation and Writing - review & editing.
Lin Lin Liu, Guang Zhang, Ying Sun: Methodology, Validation and Writing- review & editing.
Na Zhang: Conceptualization, Writing- review & editing and Funding acquisition.
Fenglian Chen, Chunhua Yang: Conceptualization, Methodology, Resources, Writing - review & editing, Supervision, Project administration, Funding acquisition

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Figures

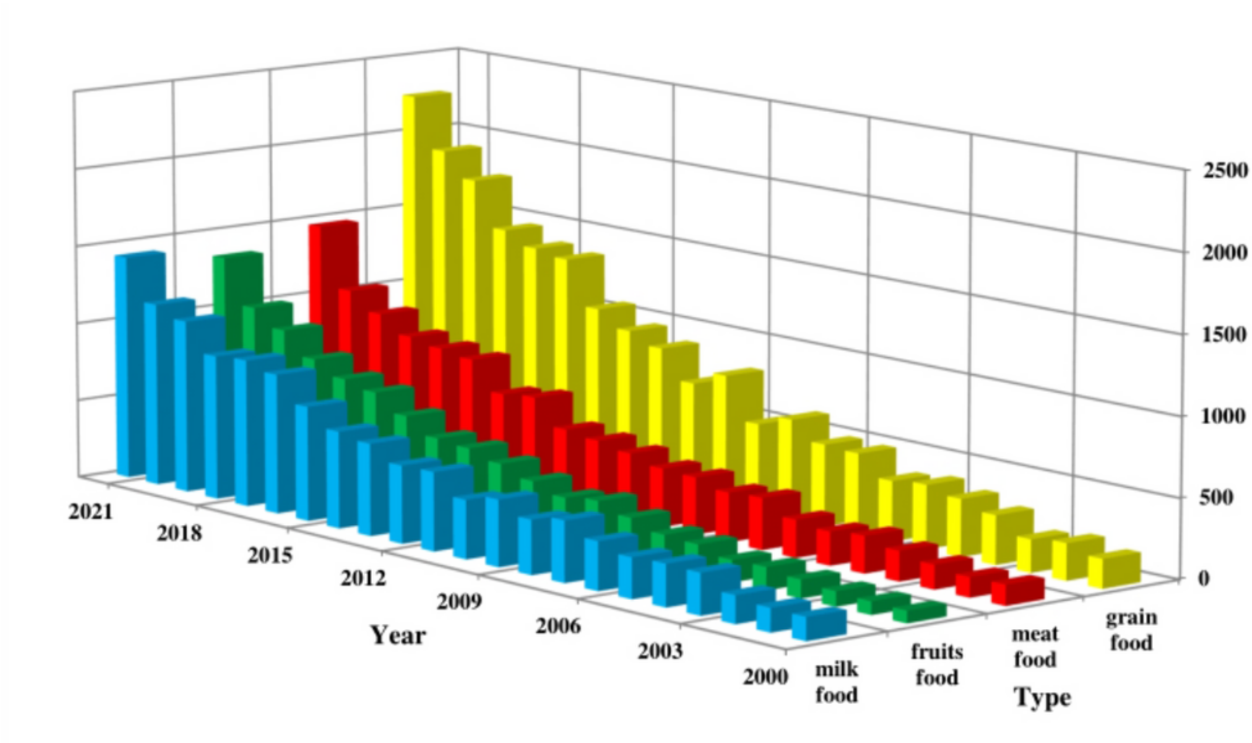

Figure 1

the application of TPA in four food from 2000 to 2021

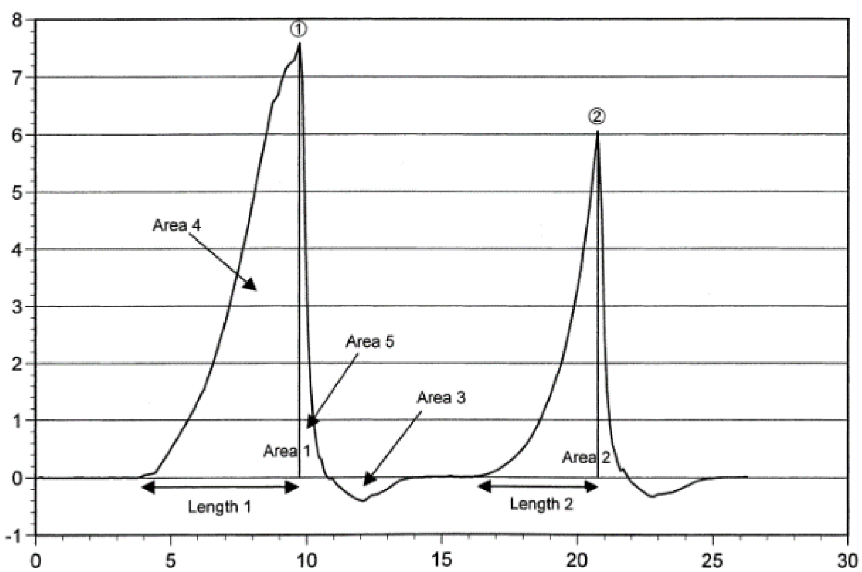

Figure 2

Typical force-by-time plot through two cycles of penetration of a longissimus thoracis rib steak to determine texture profile analysis parameters.

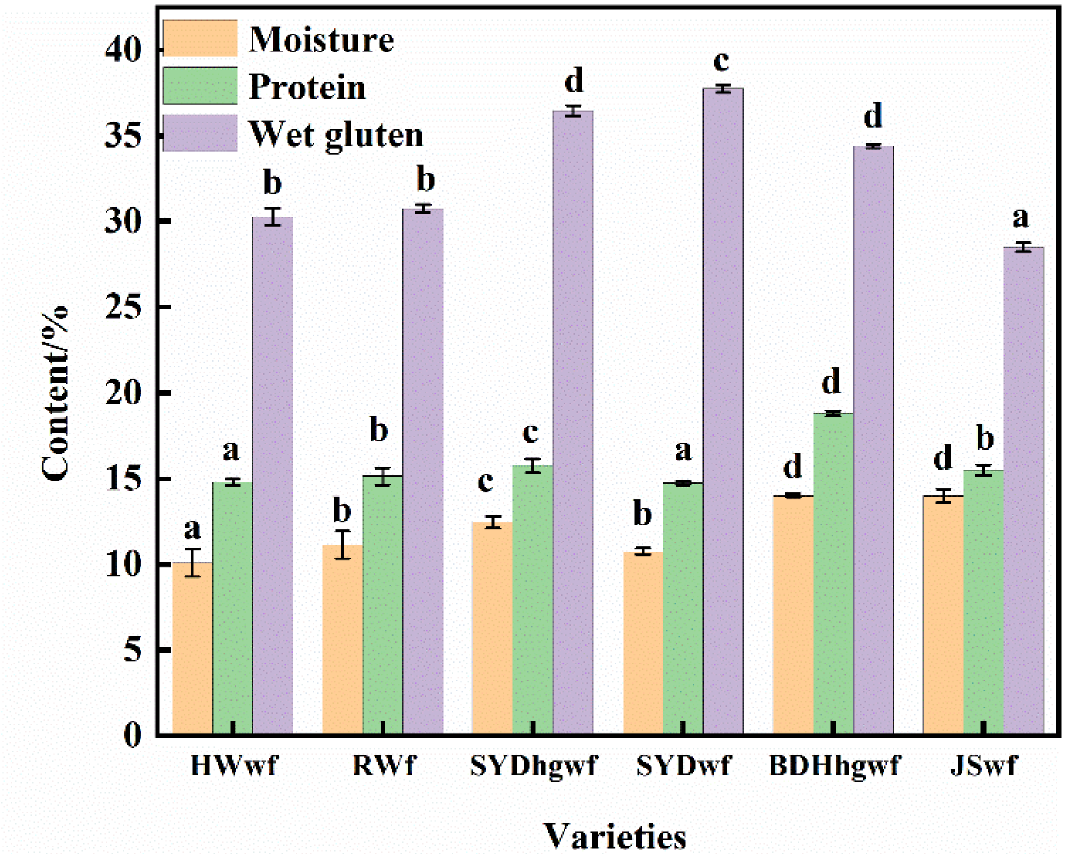

Figure 3

basic components of different wheat flour (Mean values ±SD with different superscripts letter for each attribute differ significantly ($p < 0.05$))

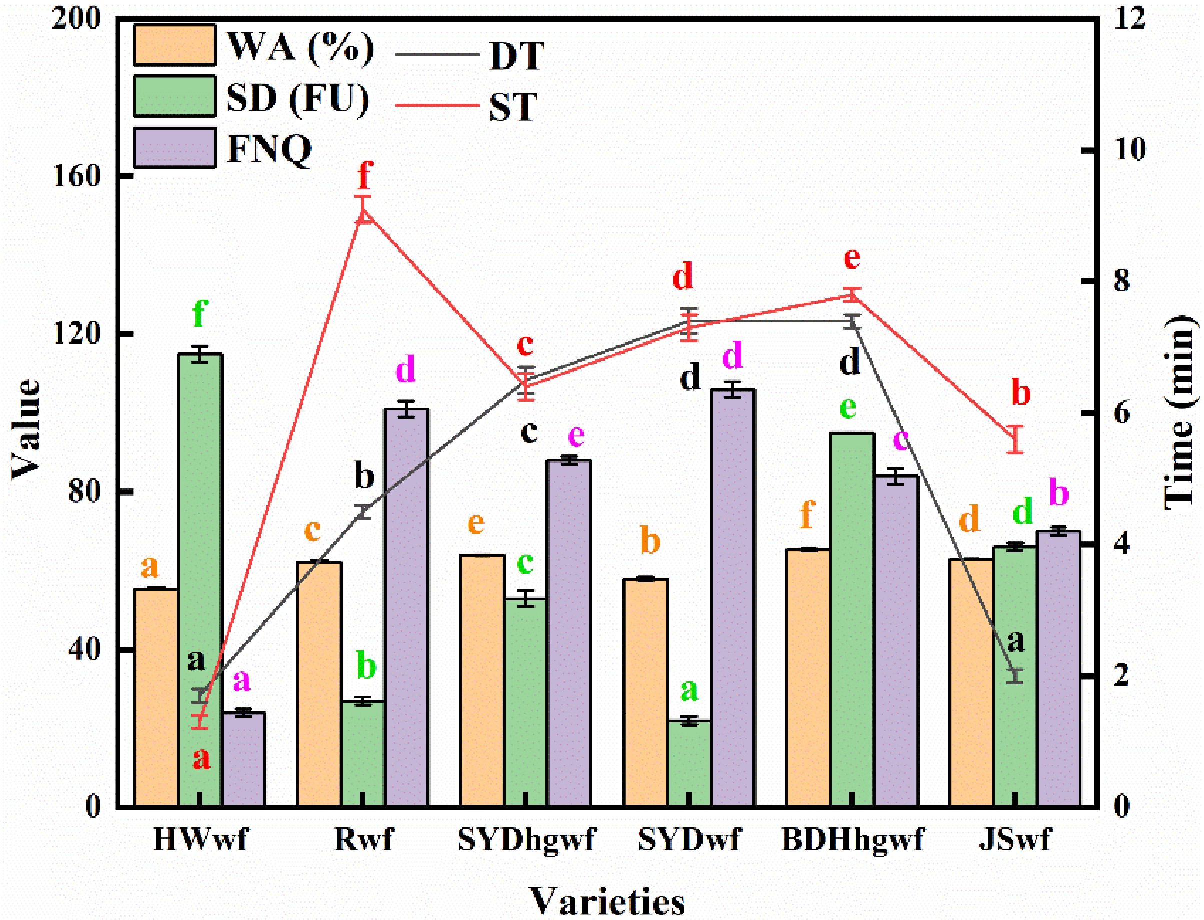

Figure 4

Farinograph parameters of different wheat flour (Mean values ± SD with different superscripts letter for each attribute differ significantly ($p < 0.05$))

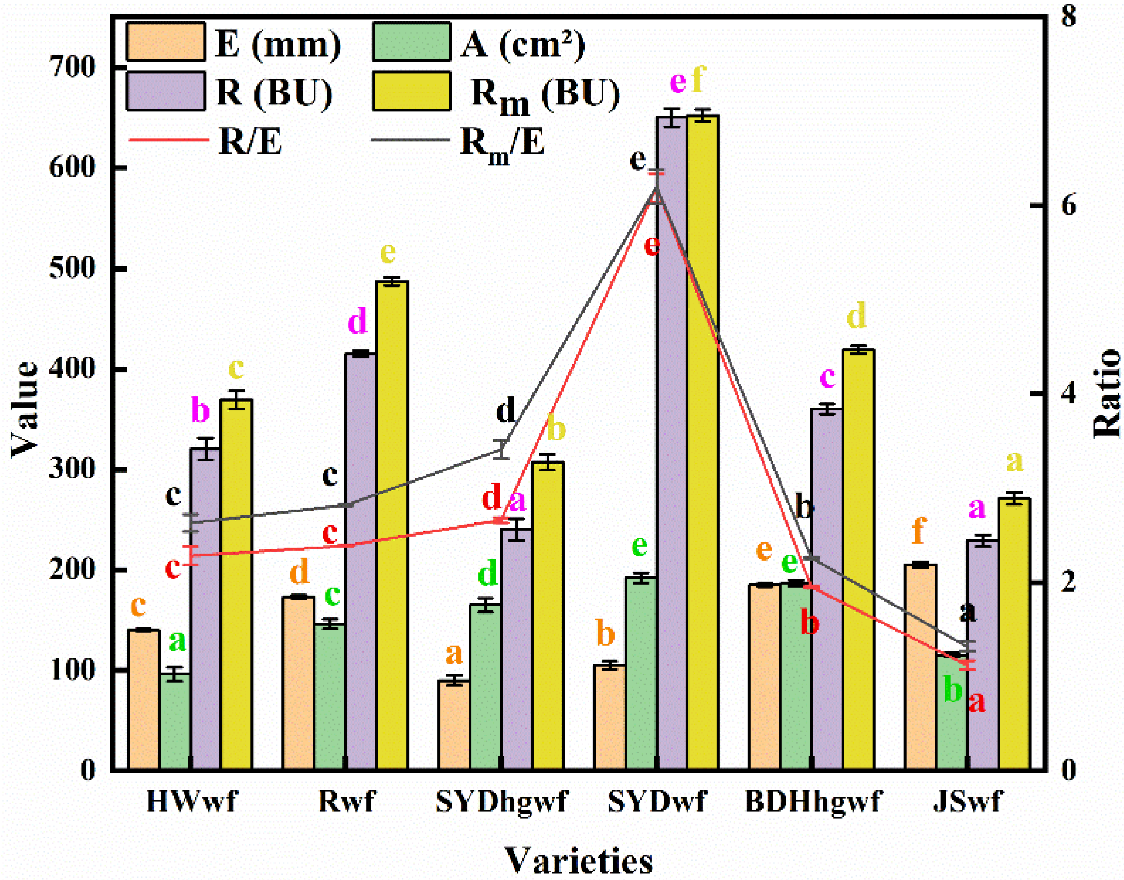

Figure 5

Extensograph parameters of dough from different wheat flour (Mean values ± SD with different superscripts letter for each attribute differ significantly ($p < 0.05$))

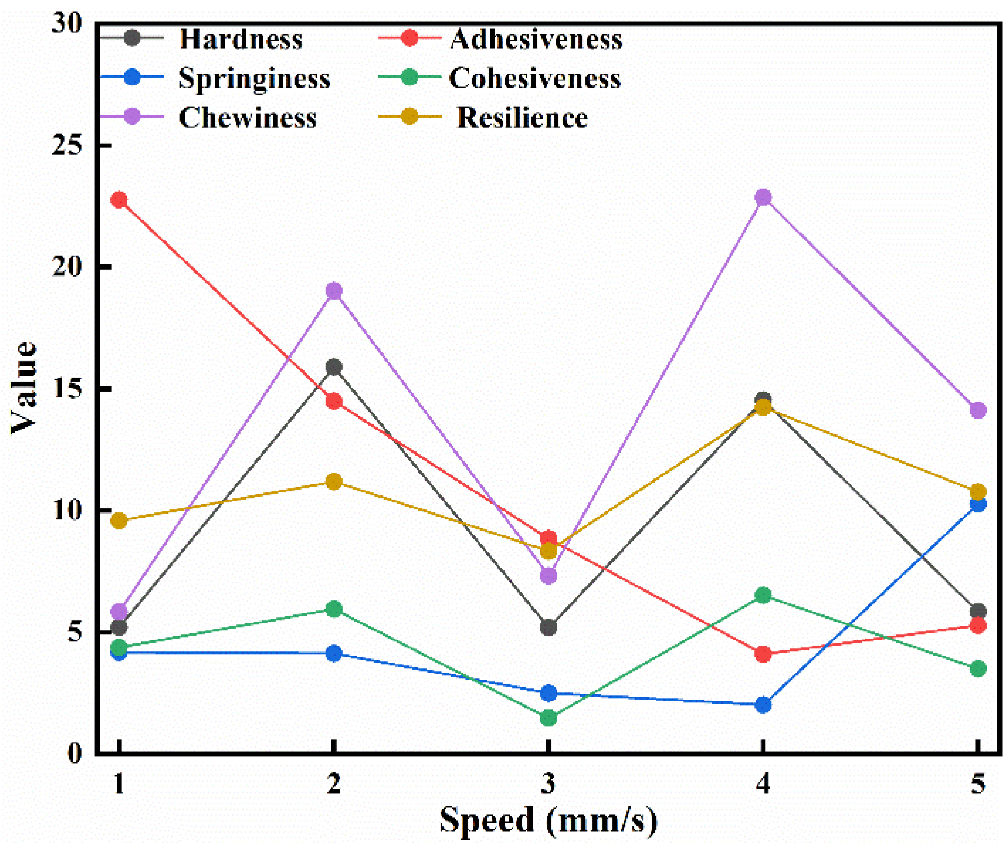

Figure 6

Results of pro-test speed on the variation coefficient of TPA in value (***: Adhesiveness is absolute value in the figur**e)

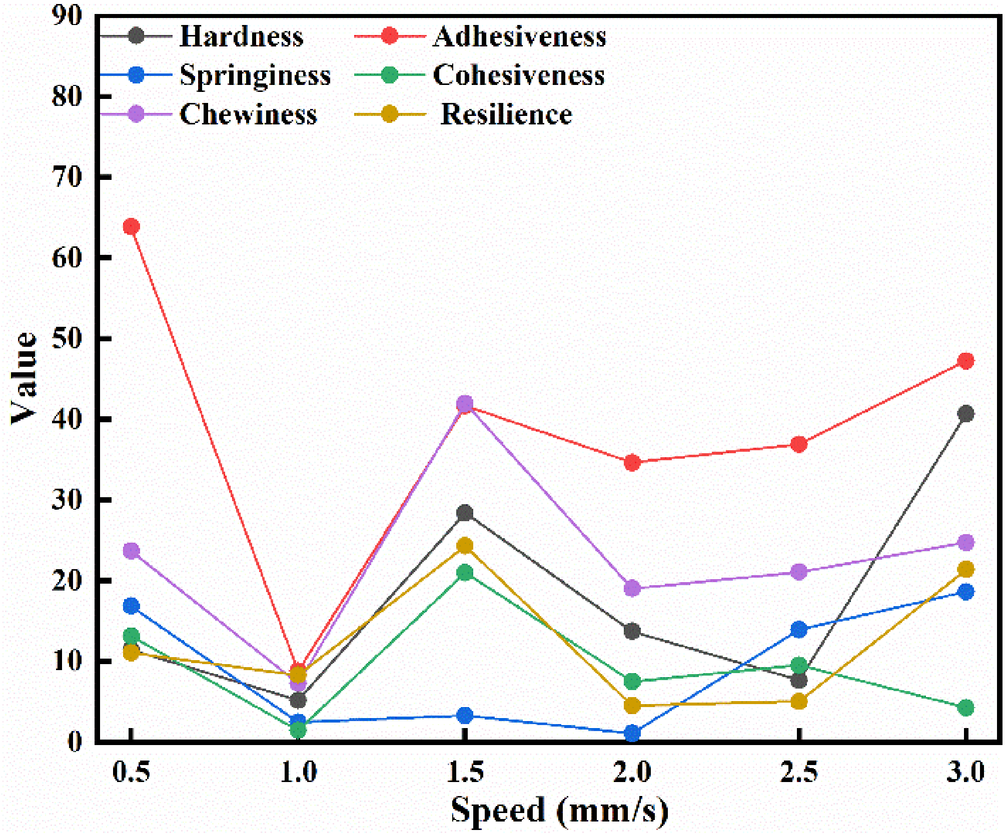

Figure 7

Results of test speed on the variation coefficient of TPA (***:Adhesiveness is absolute value in the figur**e)

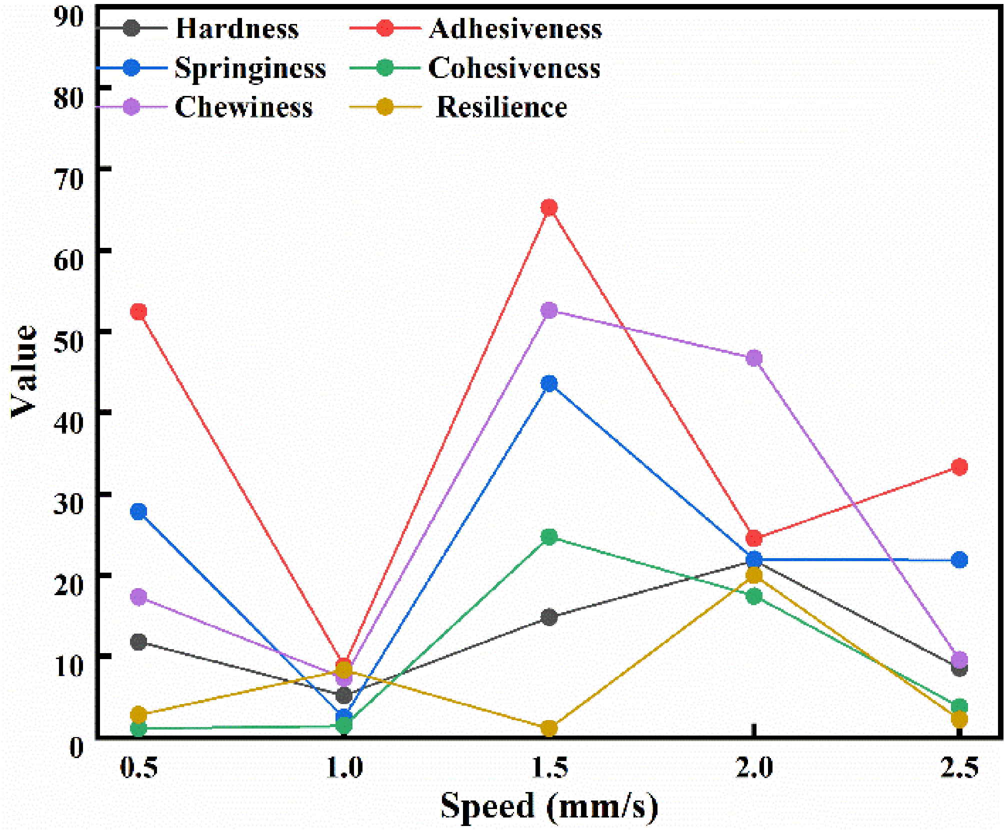

Figure 8

Results of post-test speed on the variation coefficient of TPA (***: Adhesiveness is absolute value in the figur**e)

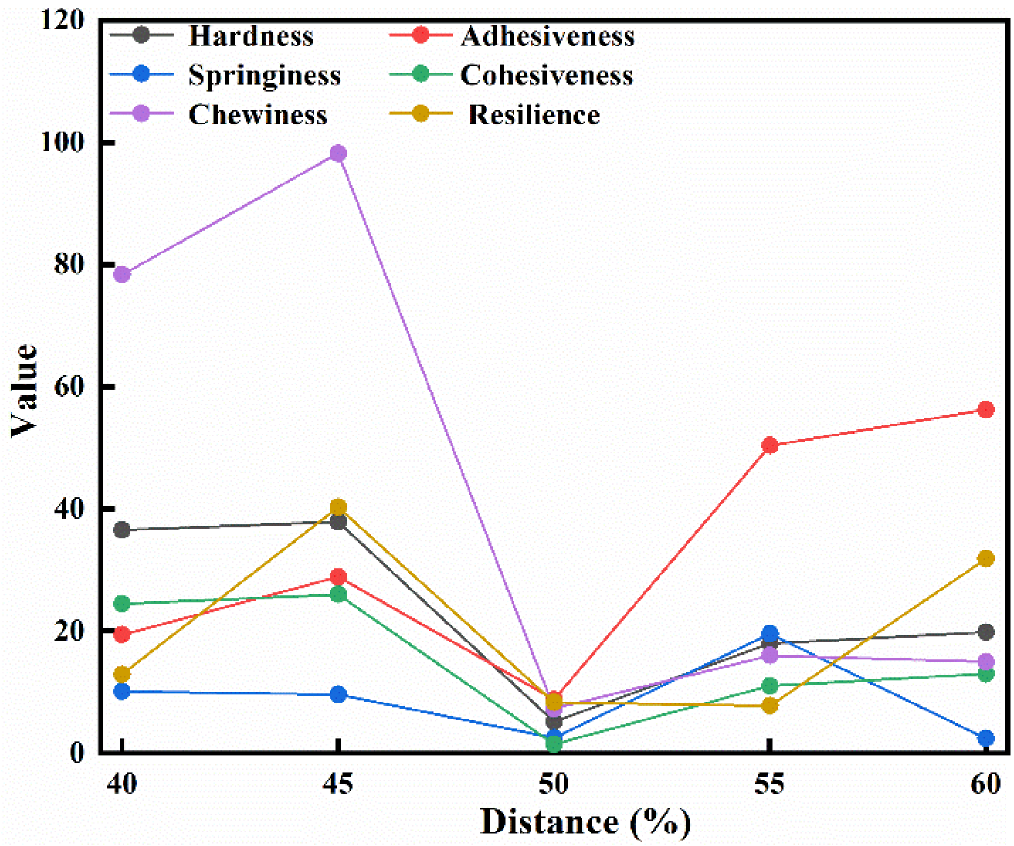

Figure 9

Results of CR on the variation coefficient of TPA (***: Adhesiveness is absolute value in the figur**e)