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Effect of arabinoxylan addition in Chinese steamed bread

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Abstract

In order to study the mechanism of arabinoxylan (AX) delaying the aging of steamed bread, the effects of AX on gelatinization, texture and starch crystallinity of steamed bread were analyzed. The results were as follows: as the storage time of steamed bread extended, the hardness and chewiness of steamed bread decreased successively in the control group, water extract AX group and enzyme extract AX group. The gelatinization of flour was decreased by both water and WEAX and EEAX, and a significant effect were observed in EEAX group. In the storage process of steamed bread, AX could inhibit the crystallinity rate of amylopectin in the freeze-dried powder of steamed bread, and the overall change range of ΔH was lower than that of control. The x-diffraction results showed that adding AX could reduce the crystallinity of steamed bread. Hence, it delays the retrogradation process and thus delay the aging of steamed bread. These results suggest that Arabinoxylan can be used as a novel additive in CSB industry, not only for the nutritional value, but also the anti-staling effect.

Keywords: arabinoxylan; staling; Chinese steamed bread.

Practical Application: The study provides a theoretical basis for a potential recycled by-product extract that not only to enhance the nutritional value of CSB, but also demonstrate a significant anti-staling effect.

1 Introduction

As the Chinese Steamed Bread (CSB) production shifted from the home-made style to modern food industrialization, the staling issue is becoming a vital issue on the CSB quality control and assurance (Zhu, 2016). Staling of steamed bread is also called "hardening", which refers to the moisture content loss and firmness increase which caused by various physical-chemical changes in the cooling and storage step. The stalling of steamed bread leads to the loss in chewiness and elasticity, making steamed bread easy to lose crumbs (Bárcenas & Rosell, 2005). Research on the anti-staling strategies which directly prolonged the shelf life of CSB has a profound meaning for the traditional staple food industrialization. A large number of researches had been done in the past decades, and it could be summarized into three following aspects: anti-staling additives, processing factors and packaging factors (Zhu, 2016). Bread and CSB staling, was complex and controversial, even without the addition of additives (Courtin & Delcour, 2002). However, for the previous researches, two significant causes have reached a consensus, which is moisture content loss and the starch retrogradation. Arabinoxylans (AX) were considered to be effective in countering these two aspects as mentioned above.

In cereals and grasses, AX is the major non-cellulose polysaccharides (70%) in wheat bran (Barron et al., 2020; Mendis & Simsek, 2014). AX accounted for 43.1% for bran and 15.3% for germ (Zhu et al., 2017). In whole-grain bread, AX is a major multifunctional component (Wang et al., 2016; Wang et al., 2020). AX multifunctional properties showed various considerably impact on the cereal food industry, such as gluten-starch separation (Frederix et al., 2004), bread making (Grootaert et al., 2007; Pihlajaniemi et al., 2020) and refrigerated dough syrup (Simsek & Ohm, 2009). Two class of AXs existed in wheat, water-extractable AX (25%-30%) and the water-unextractable AX (75%-70%). Water extractable AX are bound to the cell wall while the water unextractable AX are retained in the cell wall (Iiyama et al., 1994).

Several researches had been carried out in the past decades concerning the impact of arabinoxylans on dough, bread and CSB. For the WEAX, the research results were consensus with each other on the beneficial effect of AX addition. Baked products fortified with WEAX were less firm over the seven days storage period, which leads to a great role in the reduction of starch retrogradation and bread stalling (Izydorczyk & Biliaderis, 1995). With the addition with WEAX from rye bran, Pei`s research found that higher glutenin macropolymer were developed in the dough, which potentially decelerated the CSB staling (Wang et al., 2016). Comparing to water-extractable arabinoxylans, few researches had been carried out water unextractable arabinoxylan (WUAX). Also, WUAX showed controversial effect in baked bread and steamed bread. In baked bread, water unextractable AX showed adverse effect such as disruption of gluten network and destabilize the dough structure. However, part of the AX in WUAX was solubilized or extractable by enzyme, and the enzyme solubilized AX showed the opposite effect with WUAX on bread staling. In the presence of high activity endoxylanase, under the conversion of EEAX from WUAX, optimal functionality would

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be demonstrated without the risk of a sticky dough (Courtin & Delcour, 2002).

Hence, this research focus on the water and enzyme extracted arabinoxylan potentials on reducing the CSB staling. Generally, the first phase of CSB staling could be demonstrated by the textural change while the second phase of starch retrogradation was indicated by the re-crystallinity degree of the starch. So, in this research, four analysis was done concerning with two aforementioned parts. Firstly, the textural profile analysis and rapid viscosity analysis were done to demonstrate the water-binding and water-holding abilities of EEAX and WEAX. Secondly, differential scanning calorimeter and X-ray diffraction were carried out to illustrate the impact of EEAX and WEAX on retarding the recrystallization of the starch.

2 Materials and methods

2.1 Materials

Commercial refined flour (100 g flour: 11.1 g protein, 2.0 g fat, 74.7 g carbohydrate) from local milling company (Jinyuan refined powder: Jinyuan grain and oil, Henan, China) Commercial dry yeast (Angel Brand, Hubei, China). All chemical reagents used were of analytical grade unless otherwise specified. Wheat starch processing waste water were provided by local wheat starch processing company (Dancheng Caixin Sugar Industry Co. Ltd, Henan). Dry base composition of wheat starch waste water includes 5.7 ± 0.08% moisture, 4.34 ± 0.06% ash, 19.04 ± 0.30% protein, 24.41 ± 0.26% reducing sugar and 30.24 ± 0.35% starch. Endoxylanase (endo-1,4-β-D-xylanohydrolase EC3.2.1.8,99.99% purity) sourced from Novozyme (Copenhagen, Denmark) were used. The enzyme activity (16114.9 U/g) was determined by spectrophotometry method.

2.2 Extraction of WEAX

Wheat starch processing waste water (10% solid mass fraction) were firstly centrifuged (4 500 r/min centrifugation for 20 min). Take the upper layer and heated to 95 °C and hold for 20 minutes. Then centrifuge it again at the same condition and take the upper layer (concentrated to the 20% to 40% of the original solution). Mixed with Ethanol and standby for 4 hours. Then the precipitation was rewashed by ethanol and solublised in the water, making concentrated solution with fewer impurities. Then this concentrated solution was centrifuged again. 60% of ethanol was added to denature protein and precipitate arabinoxylan. The dry product was redissolved in water and the supernatant was freeze-dried in a (FD-1A-50 freeze drier, Beijing) then grounded by a grinder.

2.3 Extraction of EEAX

Same as above, wheat starch processing waste water (10% solid mass fraction) was used. Firstly, the pH was adjusted with buffer solution to 4.0-6.0. Then, 0.1% of xylan invertase was added to the solution. The solution was agitated for 1.5 hours at the temperature of 50 °C. Then, after the centrifugation, the supernatant was heated to 95 °C and hold for 20 minutes. Then centrifuge it again at the same condition and take the upper layer (concentrated to the 20% to 40% of the original solution). Mixed with Ethanol and standby for 4 hours. Then the precipitation was washed by ethanol again and solubilized in the water, making concentrated solution with fewer impurities. Then this concentrated solution was centrifuged again. 60% of ethanol was added to denature protein and precipitate arabinoxylan. The dry product was redissolved in water and the supernatant was freeze-dried in a (FD-1A-50 freeze drier, Beijing) then grounded by a grinder.

2.4 Preparation of the CSB and storage conditions

Preparation: Preparation and quality measuring methods were adopted from the national standard of Chinese steamed bread made of wheat flour GB/T 21118-2007 with modification. A fixed amount of AX sample was dissolved in water. The added water amount (76%) was the water absorption rate determined by farinograph (Farinograph-AX, Brabender). Then set amount of refined powder and 0.8% highly active dry yeast was added and mixed in the dough mixer for 12 minutes to form a stable dough.

Dough rolled up after many times, cut into shape (about 110 g), in a wake-up box at 35 °C, relative humidity of 88%), wakes up for 35 min. Then the steamed in the tray above boiling water for 20 minutes, take out and cool down naturally at room temperature for 1 hour. Then bread was packed into plastic bags and following analyses were carried out within the 12 hours.

Storage: With reference to the literature (Chen & Tian, 2018) samples preparation of steamed bread, stored at 4 °C condition.

The test points of texture characteristics of aged steamed bread were 24 h, 48 h, and 72h.

2.5 Sensory evaluation of steamed bread

The CSB quality was investigated using evaluation method described by Xie et al. (2022), the evaluate standard was showed in Table 1. The sensory evaluation was performed by 8 trained panelists who major in food science and technology, and the average value obtained from them was regarded as the last result. Here, the overall quality of CSB was evaluated by considering the

Table 1. The standard of sensory evaluation of steamed bread.

Project	Standard	Full mark
Specific volume	2.3 mL/g is standard 20. Decreases by 1 for every 0.1 less.	20
Surface structure	White, smooth, symmetry, pretty appearance shape 21.1-25; yellow, fold, collapse, small bubbles, flat 15.1-21; gray, depression or big bubbles, hot spot, asymmetric 1-15	25
Internal structure	Small and even 30.1-35; porosity density but uniform 21.1-30; big hole, rough 1-21	35
Taste	Elastic, strong chewy but not hard, delicious and not sticky 13.1-15; weak chewy, slightly sticky 9.1-13; hard, sticky 1-9	15
Smell	Sweet smell 3-5; peculiar smell 1-3	5

quality characteristics such as Specific volume, surface structure, internal structure, taste and smell.

2.6 Texture analysis of the steam bread

The steamed bread was naturally cooled for 1 h. The steamed bread was cut into 15 mm uniform slices by machine, and the middle two pieces were used for the test. The average value of 6 replicate experiments was obtained by P/35R probe in the TA.XT plus (Stable Micro Systems, Ltd., Godalming, UK). The sample canister was placed upright on the metal plate and the compression was repeated twice to imitate the chewing action. The test conditions were as follows: pre-test rate 3 mm/s, test rate 1 mm/s, post-test rate 5 mm/s, compression rate was 70%. Measurements were repeated for five times and the results were averaged from five tests.

2.7 Pasting properties analysis of the freeze-dried powder gel (RVA)

Pasting properties measuring method was adopted from the national standard of general pasting method for wheat or rye flour or starch using the rapid visco analyzer GB/T 24853-2010 with modification. The sample of steamed bread was firstly freeze-dried, crush, and pass 100 mesh sieves for backup use. 3 g of sample was weighed in the RVA canister and 25 mL of water were added (12% moisture basis), then the cannister were putted in RVA for testing.

Then the starch gelatinization characteristics of steamed bread freeze-dried powder were determined by a rapid viscosity analyzer (RVA-4, Newport Scientific, Warriewood, Australia). Heating was set which held the samples at 50 °C for 1 min, then the temperature increased to 95 °C at a rate of 12 °C/min, held for 2.7 min at 95 °C. Then cooling cycle starts with a rate of 12 °C/min to reduce the temperature to 50 °C. The sample was held at 50 °C for 2 min. Recorded parameters include pasting temperature, peak viscosity, trough viscosity (minimum viscosity at 95 °C), breakdown viscosity (peak viscosity - trough viscosity), final viscosity (viscosity at 50 °C) and setback viscosity (final viscosity - trough viscosity). All measurements and tests were done in triplicate.

2.8 Texture analysis of the freeze-dried powder gel

Gel test samples that prepared in the previous step were pasted into a 50 mL beaker. It was sealed by a plastic film after it was cooled to room temperature. Then the sample was held in the fridge at 4 °C for 24 h. The average value of 6 replicate experiments was obtained by P/6 probe in the TA.XT plus (Stable Micro Systems, Ltd., Godalming, UK). The test conditions were as follows: pre-test speed of 3 mm/s, test speed of 1 mm/s, post-test speed of 5 mm/s, compression rate of 25%.

2.9 Determination of crystallinity of amylopectin in steamed bread freeze-dried powder (DSC)

Weigh 2 mg of steamed bread freeze-dried powder in an aluminum box, add 6 L of deionized water, and balance it at room temperature (25 °C) for 18 hours. The test conditions were as follows: temperature 25 °C to 100 °C, the heating rate: 15 °C/min. The enthalpy value (ΔH), which represent the crystallinity of amylopectin starch in the sample, was determined by Differential Scanning Calorimeter (DSCQ20, TA instrument Inc, USA).

2.10 Determination of crystal properties of steamed bread and dough (X-ray diffraction)

The sample dough was freeze-dried then shift over 100 mesh sieves. Then the powder was stored in a pocket and store in a refrigerator at 4 °C. The crystal characteristics of steamed bread and dough were analyzed by X-ray diffraction (PANalytical, Netherlands). 0.5 g powder samples were tested in the measuring cell. The surface of steamed bread was flattened by glass slide and X-ray diffraction (XRD) scanning was carried out. The test conditions are as follows: Ni filter plate, current 40 mA, angle of incidence is 4-40°, step length is 0.020°, step time is 32 s. The data were analyzed by Jade5.0 software.

2.11 Statistical analysis

The experimental data were evaluated by analyses of variance (ANOVA) with Duncan's multiple tests and reported as mean ± standard deviation (SD) using SPSS 19.0 software (SPSS Inc, USA). Confidence interval were set at 0.05.

3 Results and discussion

3.1 The effect of AX on sensory evaluation of steamed bread

As shown in Figure 1 that the appearance and structure of the steamed bread added with WEAX are inferior to those of the blank samples, while the sensory indices of the steamed bread added with EEAX are considerably better than those of the blank samples. In accordance with Figure 1 and the criteria of sensory evaluation in Table 1, the steamed bread added with EEAX is relatively white, but the steamed bread with WEAX is darker and less glossy than the blank samples. It probably means that WEAX contains impurities such as lignin and protein, so its color affects the appearance of the steamed bread. In terms of volume, EEAX can enhance the gas-holding capacity of pores in the dough, but WEAX affects the gas-producing capacity of dough fermentation. Therefore, compared with blank samples, the specific volume of steamed bread with the addition of EEAX was increased, while the volume of the steamed bread with

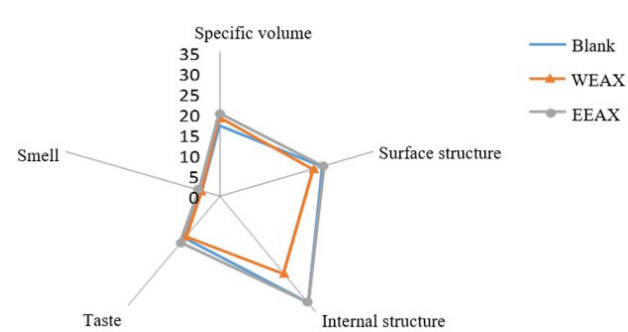

Figure 1. The effect of AX on sensory evaluation of steamed bread.

WEAX was not significantly changed. In structure, the highly viscous WEAX could bind the pores and affect the uniformity of the pore formation during the fermentation of the dough. WEAX can delay the gas escape during the steaming time, which results in the pores of the steamed bread uneven in size. However, EEAX with low viscosity can improve the structure of steamed bread, and enhance the elasticity and extensibility of the protein film, which optimizes the pore sealing caused by WEAX, and then has a good protective effect on the structure of steamed bread.

3.2 Effect of AX on texture characteristics of aged steamed bread

As it showed in Table 2, the texture of three formulations of CSB (Control, WEAX & EEAX) were analyzed. Hardness and chewability are important parameters affecting the mouthfeel of steamed bread. Hardness, which were measured by the highest deformation peak, were closely related to the CSB composition and staling. Chewability refers to the energy it takes in the mechanical imitated chewing action. Data showed that under the same storage time, both control and AX treated group showed significant increment. However, AX treated groups showed significant lower value comparing to control group. In AX treated groups, EEAX group were significantly lower than the WEAX group. AX addition significantly improves the hardness and chewability of aged steamed bread, indicating that AX effectively inhibits the aging speed of steamed bread and optimizes the quality of steamed bread. As AX can adhere to the protein surface, the close contact between starch and protein becomes loose, thus reducing the possibility of starch-protein complex formation and the degree of association. Consequently, the hardening rate of steamed bread was reduced. Besides, AX has a good water-holding capacity, which can well absorb the water molecules around the protein and starch particles. Hence, the aged dough also has a strong water-holding capacity, thus delaying the aging speed of steamed bread.

Both water extract AX and enzyme extract AX can reduce the gelatinization of steamed bread freeze-dried powder, and the effect of enzyme extract AX is significant. Potential reasons include the differences in molecular weight and ferulic acids of the extract. In these two latest works, researchers reached a consensus that the low molecular weight AX had beneficial effects on improving gluten network (Wang et al., 2019; Zhu et al., 2019). Comparing to water extract AX, enzyme extract AX had lower molecular weight (Li et al., 2013; Swennen et al., 2006). So the advantages on molecular weight may helped enzyme extract AX achieve greater effect on gluten network. Previous researches indicated that with the addition of arabinoxylan, the covalent bonds between polypeptide and polysaccharide chains would create a multiple cross-linked entity with greater molecular weight. It was controversial with the effect of these intermolecular bonds. WEAX addition was proved to strengthen gluten network and enhance the volume of gas cell in aforementioned researches (Alfaris et al., 2022; Ragaee et al., 2001). For the other three Parameters, AX addition did not show significant impact.

3.3 Influence of AX on starch pasting properties

As it showed in Table 3, the addition of EEAX and WEAX can inhibit the starch gelatinization. Except for pasting temperature, each parameter in the AX added samples are lower than the control group. Compare the two-extraction method, EEAX group showed a significantly higher impact on the starch

Table 2. The effect of AX on the textural parameters of Chinese steamed bread.

Sample	Storage Time	Texture Properties				
		Hardness	Springiness	Cohesion	Chewiness	Resilence
Blank	24 h	12613.77	83.12	0.48	5013.47	16.47
WEAX		11817.68	83.11	0.48	4557.15	16.17
EEAX		10577.90	83.14	0.49	4393.58	16.94
Blank	48 h	14113.13	81.62	0.45	5584.78	15.36
WEAX		13239.49	79.94	0.46	4646.67	15.68
EEAX		13096.31	79.62	0.45	4328.44	15.41
Blank	72 h	17426.07	81.10	0.47	7006.10	16.04
WEAX		16243.95	81.14	0.46	6553.87	16.22
EEAX		15548.13	81.29	0.46	5756.07	16.07

Note: 6 replicates were done in this test. WEAX and EEAX are extracted from wheat starch processing wastewater by water extraction and enzymatic hydrolysis process respectively.

Table 3. The RVA parameters of freeze dried steamed bread powder.

Gelatinization Properties	Blank	WEAX	EEAX
Peak Viscosity	956.0 ± 15.5a	821.5 ± 21.9b	776.5 ± 14.9c
Trough Viscosity	887.0 ± 16.8a	804.5 ± 19.1b	760.5 ± 16.3c
Breakdown Viscosity	75.0 ± 1.6a	17.0 ± 2.8b	16.0 ± 1.4b
Final Viscosity	1697.0 ± 25.3a	1470.5 ± 21.9b	1433.0 ± 21.8b
Setback Viscosity	810.0 ± 2.3a	666.0 ± 2.8c	672.5 ± 2.5b
Pasting Temperature	94.5 ± 0a	94.5 ± 0a	94.5 ± 0a

Note: Different lowercase letters a, b, c in the same row indicates significant difference, $P < 0.05$.

gelatinization.AX addition to the pasting system causes the reduction of starch concentration. Moreover, because the AX has water swelling property. AX can absorb the moisture content in pasting system, inhibit sediment particles swell and prevent the starch-protein interaction.

Consequently, AX addition can reduce wheat starch pasting properties. As it showed in Table 2, peak viscosity, trough viscosity, breakdown viscosity, final viscosity, and setback viscosity all decreased significantly. The results showed that the addition of AX had no significant effect on the pasting temperature, indicating starch concentration change had little impact on the pasting temperature. Higher pasting temperature indicated higher resistance towards swelling and amylose proportion rather than the whole starch concentration exhibited the correlation with the pasting temperature (Seetharaman et al., 2001). Peak viscosity represents the expansion degree of starch particles in the gelatinization process (Sasaki et al., 2000). The reduction of peak viscosity is beneficial for the dough fully expansion during fermentation. It will also improve the processing performance of the AX added dough. Breakdown viscosity was calculated as the peak viscosity minus trough viscosity value, which was measured of the cooked starch to disintegration (Sun et al., 2014) The breakdown viscosity and setback viscosity of starch were declined, indicating that AX could increase the thermal paste stability of steamed bread freeze-dried powder.

AX can compete with protein and starch molecules on water absorption. In the process of gelatinization, with AX addition, starch granules would less likely to swell and burst. Consequently, the setback value of the AX addition group was lower than the blank group. Also, when the temperature rises, with less starch granule burst, less starch molecules were released from the starch granule. As a result. Breakdown viscosity and setback viscosity of treated samples were lower than the control samples. Lower setback viscosity delays the stalling speed of CSB and it could extend the shelf life of CSB products. Therefore, AX addition showed beneficial effect on retarding the staling process of CSB.

3.4 Texture characteristics of steamed bread freeze-dried powder gel

The texture characteristics of gels are mainly concerned with hardness, viscosity, adhesion, cohesion, elasticity, and chewability. The texture index can directly and accurately characterize the sensory quality of the gel. The hardness of the gel is mainly caused by aging and retrogradation of starch gel, which is related to recrystallization of amylopectin and dehydration of the gel (Miles et al., 1985). Springiness refers to the measure of how much the gel structure is broken down in the first mechanical compression. It is closely related to the rubbery perception in mouth (Sanderson, 1990). Adhesiveness is a parameter that reflects the surface characteristic of the material. It depends on a combined effect of adhesive and cohesive forces, as well as viscosity and viscoelastic (Adhikari et al., 2001). As can be seen from Table 4, the texture indexes of the starch gel with WEAX and EEAX were significantly different from those of the blank sample, and the hardness, adhesiveness, gumminess and chewability indexes were significantly lower than those of the blank sample. The resilience indexes increased, but there was no significant difference in cohesion and springiness. Also, no significant differences were found between EEAX group and WEAX group.

In AX added groups, the hardness and gumminess parameters were less than the control group, indicating that the gel strength was weaker. According to the RVA test, the AX addition reduced the trough viscosity and increased its thermal stability. The cold paste viscosity decreased when the starch retrogradation value decreased. AX improved the thermal stability of steamed bread freeze-dried powder. On the one hand, the AX addition reduced the concentration of protein and starch in the gel system, weakened the intermolecular association between starch-starch and starch-protein, and reduced the degree of cross-linking between starch molecules in the formation of gel. On the other hand, in the process of cooling to form a gel, AX with high water holding capacity will prevent the leaching of water in the starch paste and reduce the retrogradation rate of the starch paste. As a result, the formed gel becomes weaker and its hardness and stickiness decrease.

3.5 Determination of crystallinity of amylopectin in steamed bread freeze-dried powder

The crystallization enthalpy (ΔH) of amylopectin in steamed bread freeze-dried powder was determined by DSC at 0 hours, 12 hours, 24 hours, 48 hours and 72 hours. △H represents the heat that was absorbed in the recrystallization of starch molecules. It can also characterize the degree of hardening (staling) of steamed bread. In Indrani`s research, heat absorption peak in aged bread presented between 50 °C-70 °C. It was because of the amylopectin staling and recrystallization. Hence, △H can be used to characterize the degree of aging (Indrani et al., 2000). With the extension of the storage time of steamed bread, starch molecules recrystallized. In this recrystallized process, starch

Table 4. The textural parameters of the gel of freeze dried steamed bread powder.

Texture Properties	Blank	WEAX	EEAX
Hardness	32.11 ± 0.90a	27.41 ± 1.15b	26.56 ± 1.05b
Adhesiveness	-26.51 ± 1.71a	-19.14 ± 1.56b	-21.66 ± 2.63b
Resilence	15.28 ± 0.94c	17.32 ± 0.96b	19.25 ± 0.44a
Cohesion	0.44 ± 0a	0.45 ± 0.01a	0.45 ± 0a
Springness	85.99 ± 1.11a	86.56 ± 0.70a	86.57 ± 1.41a
Gumminess	14.25 ± 0.32a	12.42 ± 0.30b	11.9 ± 0.41b
Chewiness	12.26 ± 0.14a	10.75 ± 0.18b	10.3 ± 0.18b

Note: Different lowercase letters a, b, c in the same row indicates significant difference, $P < 0.05$.

needed to absorb energy. Thus, Higher the △H, greater the recrystallization degree and the staling level of CSB.

As can be seen from Table 5, with the extension of steamed bread refrigerated time, △H gradually increased, indicating that the starch recrystallization content increased, steamed bread staling degree increased. Although the △H of all 3 samples significantly increased compared with fresh-made CSB, the addition of AX could effectively reduce the △H required. Hence, the recrystallization degree of amylopectin in CSB was significantly reduced. Both of the AX addition group indicated the △H was significantly smaller than that of blank steamed bread. However, statistical analysis showed that the EEAX group had a significantly higher impact than the WEAX group.

3.6 Analysis of the X-ray diffraction results of steamed bread freeze-dried powder

Starch typical crystal structure includes A, B, C and V type, etc. Naturally, no V type crystal was found in wheat starch (Bail et al., 1993). After gelatinization process, amylose reacted with lipids generating v-type crystal (Indrani et al., 2000). Since different starch have different X-ray diffraction characteristics and properties, the physical and chemical changes in the starch content will have a significant impact on the test results. The X-ray diffraction results, peak pattern, showed the crystallinity changes of starch.

Two experiments were done on the X-ray diffraction test. The first one on the fresh made CSB aimed to show the influence of AX on the starch. The second one which measured the relative crystallinity of the CSB demonstrates the effect of AX addition on retardation of the starch retrogradation. In the first experiment, as can be seen from Figure 2, peak pattern results indicated that the starch crystal structure of steamed bread flour did not change with the addition of AX, and both of them were A-type crystal peaks.

The crystal form of the three kinds of steamed bread flour dough powders is A-type crystal peak. The crystalline structure of starch type A has peak diffraction and dispersion diffraction and is composed of crystalline region and amorphous region. The characteristic peaks of steamed bread powder on the X-diffraction pattern belong to V-shape crystallization. In the second experiment, it can be seen from Figure 3 that the relative crystallinity of the steamed bread added with AX was lower than that of the blank sample, and the steamed bread added with enzyme extract AX had the lowest crystallinity. The degree of starch crystallinity was correlated with the retrogradation of starch. The results showed that AX reduced the starch retrogradation in order to retard CSB staling.

For this phenomenon, two potential reasons could be summarized. Firstly, according to the data of pasting properties of freeze-dried CSB powder in Table 3, with the two types of AX addition, key pasting parameters were all decreased. Because AX was highly hydrophilic and has a great water holding capacity, the movement of water molecules around starch granules were blocked. Consequently, AX addition hinders starch's water

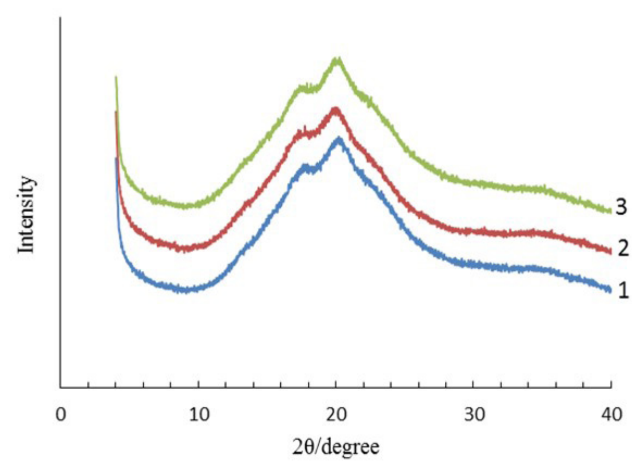

Figure 2. CSB Dough X-ray diffraction patterns.

Table 5. Enthalpy values of Chinese steamed bread flour.

Sample	Storage Time (h)	Amylopectin setback peak			
		To (°C)	Tp (°C)	Te (°C)	△H (J/g)
Blank	0	0	0	0	0
WEAX	0	0	0	0	0
EEAX	0	0	0	0	0
Blank	12	46.28	49.39	57.22	0.91
WEAX	12	44.71	48.18	56.73	0.69
EEAX	12	44.21	48.02	56.25	0.48
Blank	24	45.55	49.07	56.25	2.76
WEAX	24	45.74	48.73	56.04	2.23
EEAX	24	45.66	49.15	56.24	1.83
Blank	48	45.46	49.58	57.18	3.22
WEAX	48	45.78	48.93	56.39	2.58
EEAX (60%)	48	45.22	49.78	57.3	2.55
Blank	72	44.03	49.67	58.84	3.91
WEAX	72	44.18	49.17	57.42	3.43
EEAX	72	44.65	48.63	55.85	2.87

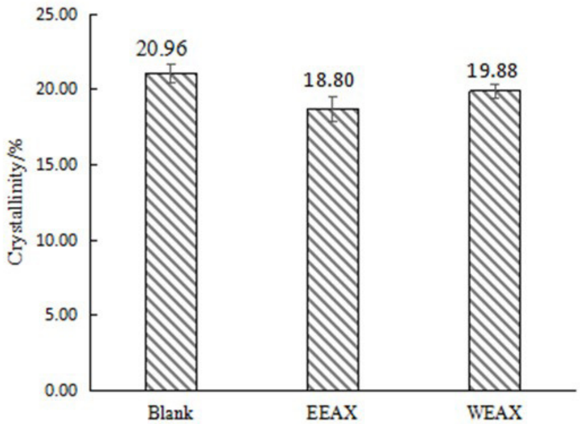

Figure 3. The relative crystallinity of crumb of Chinese steamed bread flour.

absorption and swelling, hence retarded the crystallization process. The second potential reason is that both AX can reduce the interaction between starch and starch and the formation of hydrogen bond between starch granules.

4 Conclusion

The steamed bread added with EEAX has more uniform pores, while WEAX delays the escape of gas during the steaming time, resulting in uneven pores in the steamed bread. Therefore, EEAX can better lead to changes in the sensory quality and textural properties of steamed bread than WEAX. With the prolonging of storage time, the increase of hardness and chewability of steamed bread in blank control group, water extract AX group and enzyme extract AX group decreased successively. Both water extract AX and enzyme extract AX can reduce the gelatinization of steamed bread freeze-dried powder, and the effect of enzyme extract AX is significant. Both water and enzyme extract AX could reduce the hardness, viscosity, stickiness, and chewability of steamed bread freeze-dried powder gel, and increase its recovery, but had no significant effect on cohesion and elasticity. Moreover, there was no significant difference in the effect of water and enzyme extract AX. With the extension of steamed bread refrigerated time, ΔH gradually increased, indicating that starch recrystallization content increased, steamed bread aging degree increased. The addition of AX could inhibit the recrystallization rate of amylopectin in steamed bread, and the overall change range of ΔH was smaller than that of blank steamed bread, in which the effect of enzymatic extract of AX was more obvious. The x-diffraction results showed that addition of AX could reduce the crystallinity of steamed bread, that is, AX could inhibit the recrystallization rate of starch, reduce the content of crystal in the regeneration system, and delay the aging of steamed bread. These results suggest that Arabinoxylan can be used as a novel additive in CSB industry, not only for the nutritional value, but also the anti-staling effect.

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