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Evaluation of water holding capacity and breadmaking properties for frozen dough containing ice structuring proteins from winter wheat

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ABSTRACT

The effects of ice structuring proteins (ISPs) from white wheat and storage conditions on the water holding capacity (WHC) and breadmaking properties of frozen dough were investigated. The WHC of frozen dough was measured by centrifugation and the breadmaking properties were assessed as proofing time and bread specific volume. It was found that the prolonged frozen storage and freeze–thaw cycles decreased the WHC and breadmaking properties of dough. ISPs were highly effective in increasing the WHC of frozen dough and improving the breadmaking properties. There was a strong correlation between WHC and breadmaking properties (proofing time and bread specific volume) of frozen dough.

1. Introduction

Frozen dough is widely used in the breadmaking industry. The major issue for frozen dough is the loss of quality during storage. Several problems arising from the production of bread made from frozen dough have been reported (Bail et al., 1999; Inoue and Bushuk, 1991; Inoue et al., 1994; Ribotta et al., 2001; Rosell and Gomez, 2007; Selomulyo and Zhou, 2007). These include the increase in liquid loss and in proofing time, and the decrease in the retention capacity of CO_2 and in bread specific volume. With respect to product quality, such problems can lead to a decrease in retailer and consumer acceptance of frozen dough products and thus be of economic disadvantage to producers. It is therefore important to gain a better understanding of what initiates this deterioration and to maintain the high quality of the product.

Water distribution changes in food during extended frozen storage and freeze–thaw cycles. Water holding capacity (WHC) of food is regarded as an essential quality parameter for practical applications (Mao et al., 2001). Due to the intrinsic instability of frozen dough, water may be lost when the dough is subjected to external forces. On the other hand, during extended frozen storage and freeze–thaw cycles, ice crystallization and recrystallization could contribute to the weakening of the gluten network and result in the decrease of bread quality. A strong correlation between the amount of centrifuged liquid and breadmaking properties was reported (Seguchi et al., 2003).

Antifreeze or ice structuring proteins (ISPs) can lower the freezing point of solutions noncolligatively and inhibit ice crystal growth and recrystallization during freezing (Barrett, 2001; Kristiansen and Zachariassen, 2005; Yeh and Feeney, 1996). Research has already been conducted on the effects of ISPs on the physicochemical, rheological and textural characteristics of frozen dough (Kontogiorgos and Goff, 2007; Zhang et al., 2007a,b). Changes in the distribution and size of ice crystals formed and delaying recrystallization by ISPs have direct impact on product quality.

The objective of this research was to study the WHC and breadmaking properties of frozen dough as affected by ISPs and storage conditions, and to study the relationship between WHC and breadmaking properties.

2. Materials and methods

2.1. Extraction of ice structuring proteins from winter wheat

The ISPs were obtained from winter wheat according to the method of Zhang et al. (2007a). Whole meal samples were obtained by grinding the kernels in a blade mill to pass a 1.5 mm screen and stored at −18 °C until use. ISPs were extracted from 25 g of whole meal with 250 mL of 50 mM Tris/HCl buffer (pH 7.4) using a blender

Abbreviations: ISPs, ice structuring proteins; WHC, water holding capacity; SDS-PAGE, sodium dodecyl sulfate polyacrylamide gel electrophoresis.

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at high speed (HR 2860, Philips, China). The mixture was clarified with centrifugation at 3500 g for 30 min at 4 °C, and the pellet discarded. Proteins in the supernatant were precipitated at isoelectric point pH 4.5, and centrifuged at 3500 g for 30 min at 4 °C. The precipitate was re-dissolved in 50 mM Tris/HCl buffer and dialyzed against deionized water (membrane MWCO 500 Da) at 4 °C for 16 h. The dialyzed solution was concentrated to about 5% (v/v) of the original volume by polyethylene glycol 20000 and lyophilized for 24 h on a Labconco freeze-dryer. Protein content of the powder was 86.5% by Kjeltec Auto Analyzer Unit (Foss Tecator AB, Sweden) using a nitrogen conversion factor of 6.25.

2.2. Electrophoresis

The molecular weight distribution of ISPs was estimated by sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) (Laemmli, 1970). The lyophilized sample was re-dissolved in 50 mM Tris/HCl buffer with a concentration of 1 mg/mL and mixed at a 1:1 ratio (V/V) in the SDS-PAGE sample buffer (0.125 M Tris–HCl, pH 6.8, 10% SDS, 20% glycerol, 10% beta-mercaptoethanol), and then boiled for 5 min. An aliquot of 10 μL of the sample was loaded into the gel made of 4% stacking and 12% separating gels and subjected to electrophoresis at a constant current of 15 mA per gel using a Mini-Protean III Cell apparatus (Bio-Rad Laboratories, Mississauga, ON). After electrophoresis, gels were stained with 0.1% Coomassie-Brilliant-Blue R-250 in 50% methanol and 7% acetic acid and destained with 7% acetic acid. Low molecular weight markers (97.4, 66.2, 43.0, 31.0, 20.1, and 14.4 kDa) were purchased from Sino-American Biotechnology Company (Shanghai, China).

2.3. Preparation of dough

Commercial bread flour was purchased from Eastocean Oils and Grains Industries Co., Ltd. (ADM joint venture, Zhangjiagang, China); shortening (Fortune, China), sugar, and salt were from a local market in Wuxi, China. The bread flour was analyzed with approved methods 46-12, 44-15A and 08-01 (AACC International, 2000) for moisture, ash and protein content yielding 12.8, 0.58 and 13.5%, respectively.

Dough formulation (control) was comprised of 1000 g wheat flour, 600 g water, 15 g yeast, 40 g sugar, 15 g salt, and 40 g shortening. Dough with ISPs formulation contained 3 or 6 g of ISPs (0.3% or 0.6% flour basis). All ingredients were mixed in a mixer for complete water absorption at low speed. After that, the dough was mixed at a high speed until its complete formation. After mixing, the dough was divided into 10 g pieces and 60 g pieces, respectively, and molded. Some dough pieces of 10 g were immediately subjected to centrifugation for determination of WHC and some dough pieces of 60 g were immediately used for breadmaking. Other samples were packed in polyethylene bags for freezing.

2.4. Freezing and thawing

The dough pieces were frozen in a freezer operated at about −30 °C for 120 min. After freezing, the dough pieces were stored frozen at −18 °C for 2, 4, 6, 8, and 10 weeks. During 10 weeks storage period, some dough pieces were subjected to one, two, three, four, or five additional freeze–thaw cycles. The length of each cycle is two weeks. For the thawing, the dough pieces were placed in a refrigerator at −2 °C for 24 h, which was adequate for dough to thaw completely. After thawing, the pieces of 10 g were subjected to centrifugation for determination of WHC and the pieces of 60 g were used for breadmaking.

2.5. Centrifugation

The thawed dough pieces were removed from their pans. No water drops were observed in the pan or plastic film bag. The sample was accurately weighed and added into the pre-weighed 20 mL centrifuge tube, and then centrifuged at 3000 rpm for 60 min. The clear centrifuged liquid was decanted in a dropwise manner, and the residue was weighed. The weight ratio after and before centrifugation (W/W_0) was used to characterize the WHC of dough.

2.6. Baking

The thawed doughs were placed in greased baking pans and then placed into a fermentation cabinet maintained at 30 °C and 85% RH and final proofed to a predetermined height. The experiments were repeated twice for all conditions. An average of the proofing times was recorded. The loaves were baked at 210 °C for 25 min and cooled for 30 min before being weighed. Bread specific volume was determined by the rapeseed displacement method.

2.7. Statistical analysis

Experiments were repeated three times and the results were averaged. The variance analysis procedure of the Statistical Analysis System (SAS Institute, Inc., version 8.0) was used to determine differences of WHC and baking properties between doughs after storage. A significant level of $p < 0.05$ was chosen.

3. Results and discussion

3.1. Molecular weight distribution of ISPs

The ISPs extract was analyzed by SDS-PAGE, as shown in Fig. 1. Although the molecular weight cannot be estimated with accuracy, it was resolved into a band representing polypeptides with apparent molecular mass in the range of 14–30 kDa, especially with a high intensity band around 14–15 kDa. They are within the normal range reported for plant ISPs (Griffith and Yaish, 2004).

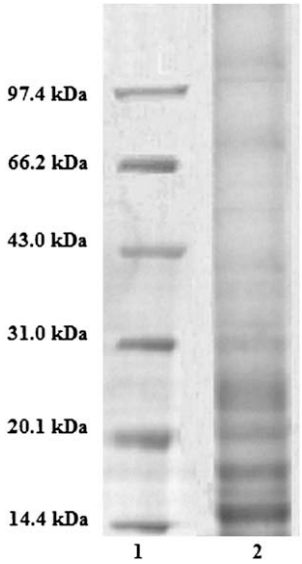

Fig. 1. SDS-PAGE gel of ISPs. Lane 1 is the molecular weight marker including rabbit phosphorglase B (97.4 kDa), bovine serum albumin (66.2 kDa), rabbit actin (43.0 kDa), bovine carbonic anhydrase (31.0 kDa), trypsin inhibitor (20.1 kDa), and hen egg white lysozyme (14.4 kDa). Lane 2 is the ISPs.