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Effects of transglutaminase on the rheological and noodle-making characteristics of oat dough containing vital wheat gluten or egg albumin☆

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ABSTRACT

Incorporating exogenous proteins into food production is a common practice for improving processing characteristics. In the present study, oat dough containing 15% (w/w, blends of protein-oat flour basis [POB]) vital wheat gluten (VWG) or 15% (w/w, POB) egg albumin (EA) was used to produce noodles with or without gluten (i.e., gluten-free). The rheological and noodle-making characteristics of oat dough containing exogenous proteins and the effects of added transglutaminase (TGase) were examined. The results indicate that the extent of TGase's modification of the thermomechanical and dynamic rheological characteristics (G' and G'') is dependent on the source of exogenous proteins in the oat dough. By adding 1.0% (w/w, POB) TGase, the cooking qualities of the resulting noodles (i.e., those containing VWG and EA) were significantly elevated with lower cooking loss; the elasticity of both types of noodles increased. The effects of TGase in different dough systems were analyzed by SDS–PAGE. In oat dough prepared with VWG, TGase was shown to catalyse the cross-linking of both oat protein and gluten protein; however, oat protein acted as the only substrate of TGase in the noodles that had been prepared with EA.

1. Introduction

The addition of exogenous proteins to food formulae is often used to improve the quality, texture, and storage stability of products (Bonet et al., 2006; Lodi et al., 2007). Oats (*Avena sativa* L.), have received increased interest in human foods due to the dietary benefits associated with β-glucans (FDA, 1997). However, the use of oats in baked products has been limited due to the inability of oat flour to form cohesive, viscoelastic dough that can retain gas, as that found in the gluten network of wheat dough. Addition of wheat gluten to oat flour improves the processing properties of the dough and the quality of the final product (Flander et al., 2007; Salmenkallio-Marttila et al., 2004). Other proteins (e.g., soybean and egg albumin) have been applied in food processing for their good gelling and emulsifying properties (Marcoa and Rosell, 2008; Singh et al., 2008).

Enzymes are widely applied in food processing to improve the textural properties and qualities of product and are generally recognized as safe. Transglutaminase (TGase, EC2.3.2.13) catalyses an acyl-transfer reaction between the γ-carboxyamide group of peptide-bound glutamine residues (acyl donors) and a variety of primary amines (acyl acceptors) (Folk and Chung, 1973; Yokoyama et al., 2004). The covalent bond of ε–(γ-Glu)–Lys is formed when the ε-amino group of lysine residues acts as acyl acceptor and cross-links with other proteins. The formation of homologous and heterologous polymers among different proteins (e.g., whey, soybean, rice, casein, avenin, etc.) results from the addition of TGase. The enzyme increases the elasticity, water-holding capability, and other functional properties of food products (Gujral and Rosell, 2004; Tang et al., 2006; Truong et al., 2004). The TGase mediated cross-linked protein could (a) re-stabilize the damaged gluten network, which is a consequence of freezing and frozen storage, and (b) provide improved rheological and bread-making properties to the frozen dough (Huang et al., 2008; Kim et al., 2008). The application of TGase in gluten-free products has also attracted increased research and industry interests in recent years (Gujral and Rosell, 2004; Moore et al., 2006).

Abbreviations: TGase, transglutaminase; VWG, vital wheat gluten; EA, egg albumin; POB, blends of protein-oat flour basis; SDS–PAGE, sodium dodecyl sulfate polyacrylamide gel electrophoresis; HPMC, hydroxy propyl methyl cellulose.

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The effects of TGase and effects of exogenous proteins on the rheological and Mixolab thermomechanical characteristics of oat dough have been previously discussed (Huang et al., 2010; Wang et al., 2009). In this study, oat dough containing 15% vital wheat gluten (VWG) and oat dough containing 15% egg albumin (EA) were used to produce oat noodles with or without gluten (gluten-free), respectively. TGase was added to examine the effects on the noodle-making characteristics and overall quality of the oat noodles.

2. Materials and methods

2.1. Materials

Commercial oat flour was used, and protein supplements of vital wheat gluten (VWG) and egg albumin (EA) were purchased from Ruixiang Biological Technology Co. and Kangde Biological Products Co., Nantong, China, respectively. Microbial transglutaminase (TGase, 100 U/g) was obtained from Yiming Fine Chemical Ltd. (Taizhou, China), and hydroxypropyl methyl cellulose (HPMC) was purchased from Hope Top Co. (Huzhou, China).

2.2. Analysis of oat flour and exogenous proteins

The proximate composition of oat flour and exogenous proteins (VWG and EA) was analyzed using approved methods of the AACCI (2000). The β-glucan content of oat flour was determined according to the method described by Lv (2005).

2.3. Dough preparation

TGase was added to the oat flour (20 g) that contained 15% (w/w, POB) exogenous proteins at the levels of 0.0%, 0.5%, 1.0%, and 1.5% (w/w, POB). These were placed in a mixer (National Mfg., Lincoln, NE) and stirred uniformly; then 90% (v/w, POB) water was added and mixed for 4 min. The oat dough was packaged using a fresh-keeping film and allowed to rest for 25 min.

2.4. Thermomechanical measurements of oat dough

Thermomechanical measurements of the oat dough were obtained using a Mixolab analyser (Chopin Technologies, Villeneuve-la-Garenne, France) according to the method reported by Huang et al. (2010) with slight modifications, i.e. a total weight of 90 g of oat dough was used for the assays rather than 50 g as reported previously. The composition of oat flour (containing 15% VWG or EA) with various concentrations of TGase (0.0%, 0.5%, 1.0%, and 1.5% w/w, blends of protein-oat flour basis, POB) was calculated by the corresponding Mixolab analysis software on a 14%-moisture basis. Thereafter, the water required for optimum consistency was added automatically to produce a dough torque of 1.1 ± 0.07 Nm. The processes for each blend were repeated twice.

2.5. Rheological measurements

Dynamic rheological measurements of the dough were determined using an AR1000 Rheometer (TA Instruments, New Castle, DE) as described previously by Huang et al. (2010). The measuring system consisted of parallel plate geometry (40 mm diameter, 1 mm gap). The dough was placed between the plates as soon as possible within 1 h of mixing, and the test was started after the dough had rested for 5 min. The rim of the sample was coated with Vaseline to prevent evaporation during measurement. Measurements were performed at 30 °C. The linear viscoelastic zone was determined by stress sweeps at 1 Hz frequency. Frequency sweep tests were performed from 0.01 to 10.00 Hz to determine the storage modulus (G') loss modulus (G'') and loss factor (tan δ) as a function of frequency. Three replicates of each measurement were made.

2.6. Protein extraction and sodium dodecyl sulfate–polyacrylamide gel electrophoresis (SDS–PAGE)

Protein fractions were extracted as described by Huang et al. (2010) from dough prepared as described above with 1.5 ml solvent. Salt-soluble proteins were extracted from 0.5 g oat dough by the addition of 1.5 ml 400 mM NaCl, alcohol-soluble proteins were extracted using 1.5 ml 60% (v/v) ethanol and glutelin with 1.5 ml SDS buffer (62.5 mM Tris–HCl, pH 6.8, 2.3% [w/v] SDS, 10% [v/v] glycerol, 5% [v/v] 2-mercaptoethanol).

Denaturing SDS–PAGE was performed using 12% separating gel (pH 8.8) and 5% stacking gel (pH 6.8). Samples (20 μl) were mixed with 10 μl sample buffer (0.01 M Tris–HCl, pH 6.8, 10.0% [w/v] SDS, 5.0% [v/v] 2-mercaptoethanol, 10.0% [v/v] glycerol, and 0.1% [w/v] bromophenol blue). Samples were heated in a boiling water bath for 5 min, and then centrifuged for 10 min at $4000 \times g$. Samples (15 μl) were loaded into each lane and electrophoresis was carried out at 12 mA for the first 20 min then increased to 20 mA for the remainder of the run. The gel was stained with Coomassie Brilliant Blue 0.25% (w/v) in 50% methanol, 10% acetic acid, and de-stained in 10% acetic acid.

2.7. Quantification of free amino groups

Quantification of free amino groups was conducted using the OPA reagent (Huang et al., 2010). 0.2 g of oat dough was suspended in 2 ml 0.1 M HCl (pH 1.0), vortexed, and centrifuged for 10 min at $10{,}000 \times g$. Then, 2.5 ml OPA reagent was added to 0.1 ml of the clear supernatant. The mixtures were allowed to react for 2 min; the absorbance was determined at 340 nm in an ultraviolet spectrophotometer. The values presented represent the means of the three replicates.

2.8. Noodle preparation and quality analysis

2.8.1. Noodle preparation

The basic ingredients in the oat-flour noodles are listed in Table 1. Water with corresponding amounts of salt (2%, w/w, POB) was added to the exogenous protein-oat flour blends, and the dough was mixed for 5 min by hand. Using a noodle press (Ohtake Noodle Machine Manufacturing Co., Ltd., Tokyo, Japan), the dough was sheeted between rollers set with a 2.5 mm gap. The sheet was folded, rolled twice, and rested for 30 min at 30 °C. The dough sheet was folded and rolled through three times each through successively decreasing roller gaps of 2.04 mm, 1.65 mm, and 1.10 mm. The final dough sheet was cut into 2.0 mm-wide noodles with a roller cutter, air dried at room temperature (ca. 22–24 °C) for 48 h. and then cut into 22 cm long strips and stored at room temperature for further use.

Table 1
Basic formulation of four oat-flour blends for noodle production with salt level of 2% (w/w, POB).

Flour blends	Oat (%)	VWG (%)	EA (%)	TGase (%)	HPMC[a] (%)	Water[b] (%)
FI	85	15	–	–	–	54
FII	85	15	–	1	–	54
FIII	85	–	15	–	4	56
FIV	85	–	15	1	4	56

[a] w/w, POB.
[b] Determined through repeated trials focusing on formation and processing characteristics of the dough during noodle making. VWG, vital wheat gluten; EA, egg albumin; TGase, transglutaminase; HPMC, hydroxypropyl methyl cellulose.