Food Chemistry 143 (2014) 9–16

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Delineating the protein changes in Asian noodles induced by vacuum mixing

Man Li, Ke-Xue Zhu *, Jing Peng, Xiao-Na Guo, Tidjani Amza, Wei Peng, Hui-Ming Zhou *

State Key Laboratory of Food Science and Technology, School of Food Science and Technology, Jiangnan University, 1800 Lihu Avenue, Wuxi 214122, Jiangsu Province, PR China

ARTICLE INFO

Article history:
Received 17 March 2013
Received in revised form 29 June 2013
Accepted 18 July 2013
Available online 26 July 2013

Keywords:
Vacuum mixing
Noodle quality
Protein change
Gluten formation
Microstructure
MRI

ABSTRACT

In this study, the effect of vacuum mixing on Asian noodle qualities was investigated based on protein components changes and gluten formation. The results showed that the proportion of salt-soluble proteins decreased in vacuum mixed noodles while alcohol and alkali soluble proteins increased. The free sulfyhydryl content decreased significantly ($P < 0.05$) in low protein (LP) noodles while slight and not significant ($P > 0.05$) decrease was detected in high protein (HP) samples. Remarkable protein aggregates were observed in non-reduced SDS–PAGE patterns for LP noodles. The changes in secondary structure were reflected by the increase in α-helix and β-sheet as well as the decrease in β-turns. Furthermore, vacuum mixing conferred a more continuous and compact microstructure to both HP and LP noodle sheets as well as an increased breaking force and extensibility. In addition, less deterioration in noodle structure and water migration was observed by magnetic resonance imaging (MRI) for vacuum mixed samples during storage.

1. Introduction

As a traditional staple food, noodle has been consumed in many Asian countries since ancient time. This cereal product is becoming increasingly popular worldwide for its convenience, nutritional quality, and palatability (Li et al., 2012). The noodle-related industry has, thus, become the world's second largest, next only to bread (Heo et al., 2011). It has been estimated that at least 12% of global wheat productions are used for processing Asian noodle products (FAO, 2005; Li, Zhu, Guo, Peng, & Zhou, 2011).

Along with the development of the modern food industry, the world food market has become more and more diversified. Nowadays, consumers are increasingly considering about certain quality standards for the food they eat, such as the appearance and taste, in addition to their healthy and nutritional qualities (Li et al., 2012). Therefore, in order to satisfy the preferences of people, especially young people, for the firm, elastic, and chewy texture of noodles; these years, a lot of additives have been employed to improve the dough rheology and noodle eating quality. Nevertheless, quite few literatures are available concerning the effect of noodle processing on the product quality. The noodle-making process typically consists of raw materials mixing, crumbly dough compounding, resting, formation of dough sheets, sheet thickness reduction by rolling, and noodle strands formation by passing the dough sheet through a pair of cutting rolls (Fu, 2008). This series of processes is essentially constant among countries for different types of noodles, which would largely affect the inner interactions in the dough and consequently, influence noodle properties and quality (Fu, 2008).

Mixing is the initial step in noodle processing; the way it is carried out determines the distribution of ingredients, their interactions, and in turn, the efficiency of processing and quality of the final product (Carini, Vittadini, Curti, Antoniazzi, & Viazzani, 2010). Compared to bread dough, the water addition level of noodles is relatively low, thus the gluten development in noodle dough during traditional mixing is minimised. Vacuum mixer has recently been designed and proposed for noodle manufacturing applications. This mixer allows the interaction of wheat flour and water to be conducted in a pressure-tight chamber, favouring uniform hydration of the surface of each individual flour granule and leading to the formation of a more homogenous water–flour mixture (Li et al., 2012; Fu, 2008). Our previous study has shown that vacuum mixing could impart a glossy and bright appearance to fresh noodles, induce an improvement of the cooking and texture properties to the final products. In addition, it was shown to enhance the interaction of flour granules and water thus reducing the mobility of water molecules in the resultant noodle dough (Li et al., 2012). However, the mechanisms underlying these qualities were still not clear at present.

Wheat proteins are the best known cereal proteins. The presence of these complex biomacromolecules, gluten proteins in wheat semolina, in particular, makes it uniquely suitable for the

* Corresponding authors. Tel./fax: +86 510 85919389.
E-mail addresses: kxzhu@jiangnan.edu.cn (K.-X. Zhu), hmzhou@jiangnan.edu.cn (H.-M. Zhou).

0308-8146/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.foodchem.2013.07.086

preparation of dough because of their visco-elastic properties. Network (three-dimensional structures) formation of wheat gluten proteins plays the major role in determining the technological quality of wheat dough. Wheat proteins are sensitive to the dough making, which will undergo complicated changes during the mixing and subsequent processes. Knowledge of the changes in wheat protein behaviours is very important to understand mechanical properties of the dough and control the finished product qualities.

To increase our insight into the behaviours of protein polymerization and gluten formation in noodle dough as affected by vacuum mixing, free –SH content and SDS–PAGE were used to evaluate the sulfydryl (–SH)-disulphide bonds (–S–S–) interchange reactions; Fourier transformed infrared (FTIR) was used to measure the changes in secondary structure; while Texture profiles, SEM and MRI were employed to have a better understanding of the enhanced gluten network under vacuum mixing at macroscopic, microscopic, and molecular level.

2. Materials and methods

2.1. Materials and proximate analysis

High protein (HP) and low protein (LP) wheat flours were obtained from the local market and stored at 25 °C during the study. Moisture, protein, and ash contents were 13.2%, 13.1%, and 0.57% for HP wheat flour while 14.0%, 7.5%, and 0.41% for LP flour respectively, which were determined according to approved methods of the AACC (2000).

Farinogram properties of the wheat flour were tested according to the ICC-standard method 115/1 (1992). Wheat flour was first weighed into the mixing bowl of the farinograph (Brabender, Duisburg, Germany) in the corresponding quantity according to its water content. The bowl was connected with a circulating water pump and a thermostat which operated at 30 ± 0.2 °C. Stability times of HP and LP flours were 17.8 and 1.6 min, respectively.

2.2. Preparation of fresh noodles

The noodle formula consisted of 1000 g of flour and 350 mL of distilled water. The dough was formed using a small vacuum mixer (Mode ZHM5-S, Zhengzhou, Henan, China) under 0.00 and −0.06 MPa respectively. The mixing speed and time were as follows: 71 rpm for 20 s (low-speed), then 135 rpm for 180 s (high-speed), and at last 89 rpm for 360 s (medium-speed). The prepared dough was placed to rest in a plastic bag for 30 min. Then, the dough crumbles were passed through a small noodle machine (Mode JMTD-168/140, Beijing, China) for 6–8 times with the roller gap reduced gradually, to get dough sheets. The dimensions of the resultant noodle strands were 1 mm in width and 0.9 mm in thickness. Two independent noodle samples were made for each vacuum degree. Then some of the samples were freeze dried for the subsequent analyses.

2.3. Fractional extraction of proteins

Freeze-dried noodle samples were ground to flour and extracted based on the method originally described by Osborne (1907) and further modified by Weiss, Vogelmeier, and Görg (1993). Salt-soluble proteins were extracted with 10% (w/v) NaCl, alcohol soluble proteins were extracted with 70% aqueous ethanol (v/v) while alkali soluble proteins were extracted using 0.2% (w/v) NaOH. Protein contents in each extract were determined using biuret method (Halloran, 1981).

2.4. Determination of free thiol group content

Free thiol group (sulfhydryl, –SH) content of the conventional and vacuum mixed noodle samples were determined according to the method described by Chan and Wasserman (1993) with some modification. 0.2 g freeze-dried noodles were suspended in 5.0 mL of reaction buffer consisting of 8 M urea, 10 mM DTNB, 3 mM ethylene-diaminetetraacetic acid (EDTA), and 0.2 M Tris–HCl, pH 8.0. The mixtures were placed on an orbital shaker (Model SHA-B, Ronghua Instrument Company, Shanghai, China) for 30 min at room temperature. After shaking, 0.5 mL of DTNB-Tris–HCl buffer was added to the reaction tube and shaked for 30 min. This solution was centrifuged at 13,600*g*, and its absorbance was read at 412 nm.

2.5. SDS–PAGE (sodium dodecyl sulphate–polyacrylamide gel electrophoresis) analysis

SDS–PAGE was performed using 10% separating gel (pH 8.8) and 5% stacking gel (pH 6.8). Each sample (50 mg for HP noodles while 60 mg for LP noodles) was stirred in 1 mL of extraction buffer (0.01 M Tris–HCl, pH 6.8, including 10% (w/v) SDS, 5% (v/v) 2-mercaptoethanol (2-ME), 10% (v/v) glycerol, 0.1% (w/v) bromphenol blue). For non-reduced proteins, extraction buffer did not contain 2-ME. Samples were heated for 5 min at 100 °C, and then centrifuged for 5 min at 8000*g*. Sample volumes of 7 μl were loaded into each well and electrophoresis was performed at 100 V during the run. The gel was stained with 0.25% w/v. Coomassie brilliant blue, and de-stained in 10% acetic acid.

2.6. Secondary structure analysis

The pulverized freeze-dried noodle samples (1 mg) were exactly weighted and ground with potassium bromide for diluting. The mixture was then carefully pressed down and the secondary structure was determined by Fourier Transform Infrared Spectroscopy FT-IR (Model NEXUS, Nicolet Co., Ltd., USA). The resolution and scan times were set as 4 cm^{-1} and 16, respectively. The data were processed by Omnic and Peak Fit software (Version 4.12). Positions of the absorbance peaks located in the amide I region were determined using Fourier self-deconvolution and second derivative.

2.7. Scanning electron microscopy (SEM)

Both the surface and cross-section of fresh noodles were mounted in glutaraldehyde (2.5%) for 2 h and rinsed with cold phosphate buffer (0.1 M) for four times and followed by a secondary fixation in osmium tetroxide (1%) for 1.5 h. The samples were then eluted in graded ethanol series (30%, 50%, 70%, 90%, and 100%) for 5 min at each gradation and isoamyl acetate was used to remove the ethanol. The samples were afterwards critical point dried. Dehydrated samples were coated with gold particles for 4 min. The images were taken using SEM (Quanta-200, FEI Ltd., Eindhoven, the Netherlands) at an accelerating voltage of 5 kV.

2.8. Facets rupture test

To evaluate the influence of the gluten network formed under vacuum mixing on the resultant noodle sheet, breaking force and extensibility were determined using a TA-XT2i Texture Analyzer (Stable Micro Systems, London, England) under the "Measure force in compression" pattern. Noodle sheets were first rolled to 1.5 mm in thickness and rested for 20 min, and then the samples were measured with the HDP/TPB probe at 3 mm/s during the whole test.