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Delineating the quality and component changes of whole-wheat flour and storage stability of fresh noodles induced by microwave treatment

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ABSTRACT

In this study, the effects of microwave treatment on the microorganism mortality and PPO activity in whole-wheat flour (WWF) and storage stability of WWF fresh noodles were investigated, as well as the rheological properties of WWF, viscosity and gelatinization properties of starch component, and polymerization and conformational changes of protein. TPC and PPO activity were largely reduced in WWF treated for over 60s. Moreover, it was amazing that microwave treatment significantly increased ($P < 0.05$) dough stability and the resistance to extension. Peak and final viscosity of starch were increased after microwave treatment, with no observable loss of birefringence; SDS-extractable proteins were limitedly decreased and protein aggregating occurred mainly on the large and medium glutenin polymers as shown by the SE–HPLC profiles. In addition, microbial growth and darkening rate of WWF fresh noodles were significantly inhibited, shelf-life of the samples was extended for 3 times after treating for 90 s.

1. Introduction

Whole-wheat foods have become increasingly popular in many parts of the world due to the advantage in nutritional quality and healthy functions. Most of the wheat products are prepared from refined flour after removing bran and germ, the two parts contain most of the dietary fiber and bioactive components (Wang, Hou, Kweon, & Lee, 2016). Compared to refined flour, whole-wheat flour (WWF) provides more protein, dietary fiber, and other traditional nutrients, including minerals and many phyto-chemicals. Consumption of whole-wheat foods has been linked to reduced risk of obesity (Geng, Harnly, & Chen, 2016), type 2 diabetes (Bae, Lee, Hou, & Lee, 2014), cardiovascular diseases (Bucsella, Molnár, Harasztos, & Tömösközi, 2016a), and certain cancers. As public awareness of eating healthy foods grows, WWF in substitution for refined wheat flour is increasingly used in preparation of (steamed) bread, cookies, breakfast cereals, pasta, and noodles.

Noodle products are the staple food in many parts of Asia. As the traditional form of Chinese noodles, fresh noodle is now attracting more and more people for its unique flavor and taste (Li et al., 2012a). Thus, fresh noodles made from whole-wheat flour (WWF) should be a major subject of scientific research to improve people's dietary pattern and the increase of functional materials intake.

Despite the beneficial effects, the bran layer also contains most of the microorganisms, polyphenol oxidase (PPO), and phenolic compounds, which lead to the rapid spoilage and darkening of the final products (Niu, Hou, Li, Wang, & Chen, 2014). Thus, the shelf-life of whole-wheat fresh noodles is usually much shorter than that of regular noodles. In addition, gluten network in whole-wheat dough maybe weakened due to the dilution effect of bran and germ, which lead to a poor taste and texture of whole-wheat food products and limit their public's acceptance. Therefore, some technological efforts are needed in order to improve the performance and storage stability of whole-wheat products.

Microwaves are electromagnetic waves in the frequency range of 300 MHz-300 GHz. Polar molecules absorb microwave energy and orient themselves with respect to the electric field (Román, Martínez, Rosell, & Gómez, 2015). The rapid change in their orientation generates heat by molecular friction. The use of microwaves in food industry has increased dramatically over the past few decades, mainly for materials heating, drying, sterilization, and

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enzyme deactivation etc. (Jian, Jayas, White, Fields, & Howe, 2015). As a physical technology, microwave treatment is generally recognized as safe, eliminating the potential residue of hazardous chemicals. During microwave heating, heat is generated throughout the material, leading to faster heating rates, compared to conventional heating where heat is usually transferred from the surface to the interior (Román et al., 2015). Therefore, microwave treatment could greatly reduce the heating time of the materials without damaging the quality attributes of the final products.

In addition, the heating effect of microwave treatment may also cause the change in pasting properties of wheat starch and structural changes of protein, leading to the changes in rheological properties of wheat dough and quality of the final products. However, to our knowledge, few published work has detailedly examined the effect of microwave treatment on the microorganism mortality and PPO activity in whole-wheat flour and physicochemical properties of wheat flour.

The objectives of this work, therefore, were to study the effect of microwave treatment on microbial survival and PPO activity in whole-wheat flour and the storage stability of fresh noodles. In addition, the rheological properties, viscosity and gelatinization behaviors, and protein aggregation and conformational changes of WWF as affected by microwave treatment were also discussed.

2. Materials and methods

2.1. Materials

Whole-wheat flour was manufactured by China Oil & Foodstuffs Corporation, in which the contents of moisture, ash, protein, and fat in which were 13.50 ± 0.05, 0.85 ± 0.01, 10.10 ± 0.11, and 1.50 ± 0.03 g/100 g flour, respectively. Table salt was purchased from the local market. All drugs and reagents used were of analytical grade.

2.2. Microwave treatment

300 g of WWF was weighed into microwave-safe containers and treated at 700 W for 0 s, 30 s, 60 s, 90 s, and 120 s, respectively using a special microwave equipment (Model P70D20L, Guangzhou, China). Immediately after treating, the samples were spread in an aseptic tray and cooled, passed through a 60 mesh sieve (223 mm) to remove any lumps and stored in sealed containers in a cold room (5–7 °C) until use. Two independent samples were prepared at each treating time.

2.3. Determination of total plate count (TPC)

WWF samples were determined after microwave treatment for different times, while fresh noodles were analyzed periodically during the shelf-life study. TPC was examined according to GB/T 4789-2008 (Code of National Standard of China, 2008) with some modification. The sample (25 g) was put into 225 mL of 0.85% aseptic physiological saline, and the mixture was shaken in a stomacher bag using a stomacher machine (Lab-blender 400, Seward Laboratory) for 60 s. Serial dilutions were then prepared using 0.85% aseptic physiological saline and 1 mL of the appropriate dilutions was pour plated onto sterile plate count agar (PCA) plates. The plates were then incubated at 37 °C for 48 ± 2 h.

2.4. Determination of polyphenol oxidase (PPO) activity

The extraction of polyphenol oxidase from WWF was conducted according to the report of Fuerst, Xu, and Beecher (2008). 4 g of flour samples was incubated in 20 mL of extraction buffer (0.1 M phosphate-citric acid buffer, pH 6.0) in a 50 mL centrifuge tube and shaken at 4 °C for 12 h. PPO activity was determined by measuring the absorbance of the reaction system at 420 nm using a spectrophotometer (Model TU-1810, Beijing, China), with catechol as the substrate. The PPO activity was calculated as the difference in the absorbance of WWF sample and control and expressed as Δ420/min·g flour.

2.5. Farinograph and extensograph tests

The behavior of the microwave treated WWF dough during development and mixing was tested with the help of Farinograph-E (Brabender, Duisburg, Germany), according to the standard procedure (ICC 115/1). WWF was first weighed into the mixing bowl 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. The following farinograph parameters were determined: (1) water absorption (WA), (2) development time of dough (DT), (3) stability time of dough (ST), and (4) the degree of softening of dough (DS).

For extension tests dough was prepared using the Farniograph-E and then conducted in accordance with the standard procedure (ICC 114/1), using the Extensograph-E (Brabender, Duisburg, Germany). A piece of dough (150 g) was moulded on the balling unit of the Extensograph and shaped into a standard cylindrical shape. The test piece was allowed to rest for 45 min in the Extensograph rest cabinet at 30 °C. The following parameters were determined: (1) extensibility, (2) resistance to extension, at constant deformation (50 mm), (3) ratio number, and (4) energy.

2.6. Viscosity analysis

Pasting properties of WWF treated for 0 s, 30 s, 60 s, 90 s, and 120 s were determined with a Rapid Visco Analyzer (RVA, Model Super-3, Newport Scientific, Warriewood, Australia), according to AACC method 76-21 (AACC International, 2000). Suspensions were made using pure deionized water and the treated flour, the sampling weights of which were calculated based on the water content of WWF. The mixtures were manually homogenized using the plastic paddle right before the RVA test, and then the tests were conducted in a programmed heating and cooling cycle.

2.7. Birefringence observation

Birefringence was directly observed with the flour samples suspended in a solution of water–glycerol (1:1). Both bright-field and polarized-light microscopic observations were performed using a polarizing microscope (Model BK-POL; Olympus Corp, Japan).

2.8. Size exclusion high-performance liquid chromatography (SE-HPLC) analysis

The solubility and molecular weight distribution of proteins in microwave treated WWF samples were determined using SE-HPLC (LC-20AT, Shimadzu, Kyoto, Japan) according to the method described by Luo et al. (2016). 15 mg of flour samples (dry basis) were mixed with 1 mL of sodium phosphate buffer (50 mM, 1% SDS, pH 7.0). All samples were stirred for 10 min and centrifuged at 8000 r/min for 5 min. And then the supernatant was collected and filtrated using a 0.45 μm millipore filter. A 20 μL aliquot of each supernatant was loaded into a TSK G4000-SWXL analytical column (Tosoh Biosep, Japan), and eluted with sodium phosphate buffer (50 mM, 1% SDS, pH7.0) at a flow rate of 0.7 mL/min. The elution curve was detected at 214 nm and peak areas were calculated.