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Delineating the physico-chemical, structural, and water characteristic changes during the deterioration of fresh noodles
Understanding the deterioration mechanisms of fresh noodles

Man Li [a,b,*], Meng Ma [b], Ke-Xue Zhu [b,*], Xiao-Na Guo [b], Hui-Ming Zhou [b]

[a] School of Food Science and Engineering, Qingdao Agricultural University, Qingdao 266109, Shandong Province, PR China
[b] State Key Laboratory of Food Science and Technology, Collaborative Innovation Center of Food Safety and Quality Control in Jiangsu Province, School of Food Science and Technology, Jiangnan University, 1800 Lihu Avenue, Wuxi 214122, Jiangsu Province, PR China

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ABSTRACT

In this study, changes in fresh noodles during storage were evaluated at the physico-chemical, structural, and molecular levels. An increase in TPC and decrease in L^* value mostly occurred during the first 24 h; the pH value significantly decreased ($P < 0.05$) and proteins were partially depolymerized with the deterioration of fresh noodles, as evidenced by free amino acid determination and SDS-PAGE. Changes were also detected in the pasting and viscosity properties of the starch component. Moreover, the water sorption isotherm of fresh noodles decreased during storage, and the NMR transverse relaxation peak shifted right with an increased peak area between 10 and 100 ms. MRI images showed that with increased storage time, the original structure was damaged and water distribution became non-uniform and migrated to the surface. TPC, pH, and L^* value were selected as the visualized parameters to characterize the fresh noodle deterioration, based on the correlation and factor analyses.

1. Introduction

Noodle, as the staple food in most Asian countries, is widely enjoyed throughout the world and is the food of choice for people of all ages because of its variety, versatility, and mouthfeel (Choy, Hughes, & Small, 2010). Asian noodles are different from pasta products in terms of the raw materials, shaping processes and consumption regions (Li, Zhu, Guo, Brijs, & Zhou, 2014). Now, noodles are a staple food, second only to bread worldwide.

For quite a long time, fine dried noodles and instant fried noodles have accounted for most of the noodle production because of their convenient preservation. However, these deep drying processes may destroy the flavor, texture, and nutritional properties of noodle products (Li et al., 2012). For this reason, fresh noodle, as the initial form of Chinese noodles, is now popular with more people because of its natural flavor and taste (Cai, 1998). However, a major defect in fresh noodles is that they are extremely subject to deterioration, due to their high moisture content and abundant nutrients. This defect results in a short shelf-life if not stored under refrigeration (Xu, Hall, Wolf-Hall, & Manthey, 2008).

The short shelf-life of these products has resulted in huge waste and potential food poisoning. Substantial effort has been channeled towards the preservation of fresh noodle products, such as preservatives (both chemical and natural), irradiation, and MAP (modified atmosphere packaging). Most of these studies highlight the antibacterial effect of these technologies, and less work has been done to elucidate the types of quality changes and their dynamics during the deterioration of fresh noodles.

Ensuring quality retention in fresh noodles continues to be challenging. During storage, fresh noodles undergo some complicated physicochemical and biochemical changes, except for the microbial proliferation and metabolism (Huis in't Veld, 1996). These changes occur at different rates and to different extents, causing significant quality losses during storage and consumption and leading to the final deterioration of the products. Ren, Wang, and Li (2010) found that the sensory quality, moisture, and wet gluten content of fresh noodles decreased while the acidity and total plate count (TPC) increased. Ghaffar, Abdulamir, Bakar, Karim, and Saari (2009) concluded that microbial growth and a decrease in the pH value were the most obvious characterizations during the deterioration of fresh noodles. However, they also indicated that these changes did not exactly coincide with the deterioration process,

* Corresponding authors at: School of Food Science and Engineering, Qingdao Agricultural University, Qingdao 266109, Shandong Province, PR China (M. Li).
E-mail addresses: manliqau@163.com (M. Li), kxzhu@jiangnan.edu.cn (K.-X. Zhu).

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indicating the effect of other quality parameters and certain component changes on noodle spoilage (Dainty, 1996; Jensen, Oestdal, Skibsted, Larsen, & Thybo, 2011). Understanding the underlying mechanisms that drive noodle deterioration and their dynamics is essential for optimized or alternative technologies to be developed, allowing for optimized product quality and prolonged shelf-life.

The objective of this study, therefore, is to investigate the physico-chemical, biochemical and microbial changes in fresh noodles during storage at room temperature (25 ± 1 °C), aiming for a complete understanding of the precise mechanisms and dynamics of noodle deterioration, which may enable identification and use of optimized or alternative strategies. Moreover, this study may also provide insights into the changes in the structural and molecular levels during deterioration, generating a theoretical basis for better preservation.

2. Materials & methods

2.1. Materials and proximate analysis

Wheat flour was obtained from China Oil & Foodstuffs Corporation (Hebei, China), moisture, ash, and protein contents in which were 13.5%, 0.57%, and 13.0%, respectively. All chemical reagents were of analytical grade.

The water content was determined according to the AACC 44-15A (2000). Water activity (a_w) was measured by a Novasina Thermoconstanter (Model Labswift-aw, Novasina, Switzerland) based on the manufacturer's specifications. The pH value was measured with a pH meter (PHS-3C, Shanghai, China).

2.2. Fresh noodle preparation

Under the conditions of analog industrial production, the lab, including all instruments and packing materials, was sterilized using ultraviolet radiation. The noodle formula consisted of wheat flour and distilled water with a proportion of 100: 34 (w/w). Noodle dough was formed with a Kitchen Aid mixer (St. Joseph, MI, USA) with the following mixing parameters: 90 rpm for 120 s (low-speed) and then 60 rpm for 360 s. The obtained dough crumbles were allowed to rest in a sterilized plastic bag for 20 min, which were then passed through an experimental noodle machine (Model JMTD-168/140, Beijing, China) for 6–8 times to obtain dough sheets. The strands of the resulting noodles were 1 mm in width and 0.8 mm in thickness. Two independent fresh noodle samples were prepared and each batch was analyzed (three times). For some assays, fresh noodles were used and, in some cases (SDS-PAGE, GMP weight, swelling power, and viscosity analysis), freeze-dried samples were required. Quality assessments on fresh noodles were performed at 0 h, 12 h, 24 h, 48 h, and 72 h of storage.

2.3. Microbiological analysis

The fresh noodle sample (25 g) was placed into 225 mL of 0.85% aseptic physiological saline (PA), and the mixture was homogenized using a lab blender (Stomacher 400, Seward, England). Gradient dilutions were prepared using PA, and 1 mL of the appropriate dilutions was pour plated onto sterile plate count agar plates to determine the total aerobic plate counts (TPC). The plates were then incubated at 37 °C for 48 ± 2 h (GB/T 4789-2008, 2008). Mold and yeast counts were determined on rose bengal agar after incubation at 28 °C for 5 days. Thermoduric bacteria were recognized as the residual TPC in dilution after 10 min in boiling water.

2.4. Color measurements

A chroma meter (Model CR-400, Tokyo, Japan) with the CIE 1976 L^*, a^*, and b^* color scale was used to measure the color of the fresh noodle sheets. The L^* value is a measure of the brightness, which is reported as an indicator of noodle darkening (Li, Luo et al., 2012). Noodle sheets were cut into pieces of approximately 5 cm in diameter, and the measurement was performed within 5 min after cutting.

2.5. Determination of FAA

To investigate the changes in the fat component during storage, the fatty acid value (FAA) was evaluated according to the method by Rose, Ogden, Dunn, and Pike (2008). Fresh noodle samples (10 g) were weighed into a 150-mL Erlenmeyer flask with 50 mL of absolute ethanol. The flasks were placed in an oscillator (Model SHA-B, Shanghai, China) at 140 rpm for 10 min. Then, the mixture was filtered into a 50-mL graduated tube. Liquor (25 mL) was then transferred into another 150 mL flask and 20 mL of double-distilled water was added to precipitate the alcohol soluble proteins. Then, the mixture was titrated using 0.1 M KOH-ethanol solution with phenolphthalein as the indicator.

2.6. Textural properties

Fresh noodles were initially cut into strands of 20 cm in length and sealed. Twenty noodle strands were placed in boiling water (450 mL) and cooked to the optimal cooking time. The hardness, adhesiveness, springiness, and chewiness of cooked noodles were periodically determined using a Texture Analyzer (Model TA-plus, London, England). Determinations were conducted at 25 ± 1 °C exactly 10 min after cooking with the HDP/PFS probe and calculated under the pattern of texture profile analysis (TPA) at optimal test conditions as follows: strain, 75%; pretest, test and post-test speed, 0.8 mm/s; and interval time, 2 s.

2.7. Free amino acid (FAA) determination

Free amino acids were quantified to certify the decomposition of proteins during deterioration. Samples were analyzed using a High Speed Amino Acid Analyzer (HP 1100, Agilent, USA) with an ODS Hypersil column. Lyophilized noodle flour sample (approximately 1 g) was accurately weighed and precipitated with a 10% solution of trichloroacetic acid. The mixture was then filtered and the filtrate was used for determination.

2.8. Glutenin macropolymer (GMP) wet weight measurement

GMP was isolated from the lyophilized noodle flour using the method described by Ong, Ross, and Engle (2010) with some modifications. The samples (1.4 g) were incubated in 28 mL of 1.5% SDS and shaken in water bath at 37 °C for 30 min. The mixture was centrifuged at 8000*g* for 10 min, the supernatant (SUP) was removed and the gel-layer was collected as GMP and weighed.

2.9. SDS-PAGE

SDS-PAGE was performed with a 10% separation gel (pH 8.8) and 5% stacking gel (pH 6.8). Each lyophilized noodle sample (50 mg) was placed in 1 mL of extraction buffer based on the formula reported by Li, Zhu et al. (2012). Samples were heated for 5 min in boiling water and centrifuged at 8000*g* for 5 min. Sample volumes of 7 μL were loaded into the gel, and the voltage of electrophoresis was 100 V during the run. The gel was stained using 0.25% (w/v) coomassie brilliant blue and destained with 10% acetic