LWT - Food Science and Technology 80 (2017) 364–370

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Analysis of moisture distribution and texture of quick boil spaghetti

Kentaro Irie [a, c, *], Toshio Kawahara [a], Toru Hirauchi [a], Akemi K. Horigane [b], Mitsuru Yoshida [b, c]

[a] Research Center for Basic Science, Nisshin Seifun Group Inc, 5-3-1 Tsurugaoka, Fujimino-City, Saitama 356-8511, Japan
[b] National Food Research Institute, NARO, 2-1-12 Kannondai, Tsukuba-City, Ibaraki 305-8642, Japan
[c] Department of Food Science and Technology, Nippon Veterinary and Life Science University, 1-7-1 Kyonancho, Musashino-City, Tokyo 180-8602, Japan

ARTICLE INFO

Article history:
Received 15 September 2016
Received in revised form
27 January 2017
Accepted 14 February 2017
Available online 20 February 2017

Keywords:
Pasta
MRI
T_2 images
Moisture profile
Mechanical properties

ABSTRACT

Lengthwise grooving was adopted to produce quick boil spaghetti with standard thicknesses after boiling. Ordinary dried spaghetti with a 1.6 mm diameter (Sample A, 7 min boiling time) was compared to quick boil spaghetti samples, namely spaghetti with a V-shaped groove (Sample B, 4 min boiling time) and spaghetti with three windmill-shaped grooves (Sample C, 3 min boiling time). The quick boil spaghetti samples had lower moisture content (58–59 g/100 g) than Sample A (63 g/100 g) after cooking. The spin-spin relaxation time (T_2) magnetic resonance images during boiling showed that the region around the tips of their grooves absorbed water and swelled particularly rapidly resulting in closure of the grooves. While the region with low moisture content at the core of the strand after boiling was round in Sample A, those in Sample B and C were U-shaped and like a triangle, respectively. The shearing test force-strain curves of boiled Sample B and C varied depending on the shearing direction, which reflected their non-concentric moisture distributions. The high moisture region at the boiled spaghetti surface did not have a large effect on the mechanical properties.

1. Introduction

Several varieties of dried quick boil spaghetti have been commercialized worldwide, including in Japan. These pastas require 3–4 min of boiling, which is about half the time required to boil ordinary dried spaghetti (1.6 mm diameter, standard cooking time of 7–8 min). The benefits of quick boil spaghetti are reduced cooking time and associated fuel expenses, thereby decreasing waiting times for home consumers and restaurant customers, and being more ecological due to less energy consumption.

In order to decrease boiling times, the distance from the surface to the core of the spaghetti should be decreased to allow rapid water penetration to the core. One method to accomplish this is by producing thin spaghetti; however, to produce quick boil spaghetti with a standard thickness after boiling, lengthwise grooving (along the strand) has been adopted for rapid water penetration to the core region. There are several types of grooves for quick boil spaghetti; V-shaped (JP 3658477 B2, 2005), N-shaped (JP 4796083 B2, 2011), M-shaped (JP 4970198 B2, 2012; JP 5132255 B2, 2013; JP 5345229 B2, 2013; JP 5746673 B2, 2015), clover-shaped (JP 2001-17104A, 2001), windmill-shaped (JP 5102252 B2, 2012), and spaghettis that have a hollow core (JP 2014-14350A, 2014; JP 5771390 B2, 2015; JP 2015-204835A, 2015). Some of these spaghetti varieties fail to undergo complete closure of grooves or do not produce round cross sections at the closure of the grooves after boiling. Some types of quick boil spaghetti lack firmness when boiled until their grooves close. Both appearance and texture after cooking are important factors to consider when designing high quality quick boil spaghetti.

Factors that determine the texture of boiled pastas and noodles are thought to be the moisture content, gelatinization of starch, and formation of the gluten network. The structure of boiled pasta is generally described as a compact matrix, with the starch granules trapped in a network formed by gluten proteins (Cunin, Handschin, Walther, & Escher, 1995; Resmini & Pagani, 1983). Moisture distributions in pastas and noodles during the boiling process are not homogenous. Rapid increases in moisture content at the surface,

Abbreviations: MR, magnetic resonance; MRI, magnetic resonance imaging; NMR, nuclear magnetic resonance; RF, radio frequency; MSME, multi-slice multi-echo; ISA, image sequence analysis.

* Corresponding author. Research Center for Basic Science, Nisshin Seifun Group Inc, 5-3-1 Tsurugaoka, Fujimino-City, Saitama 356-8511, Japan.
E-mail address: irie.kentaro@nisshin.com (K. Irie).

http://dx.doi.org/10.1016/j.lwt.2017.02.027
0023-6438/

which directly contacts the boiling water, are observed due to starch granules absorbing water and gelatinizing during the early stage of boiling. The moisture content of the strand core increases later, following the penetration of water along with the progression of gelatinization from the surface to the core. As a result, a moisture gradient from the surface to the core can be observed in cross sections of boiled pastas and noodles using magnetic resonance imaging (MRI) and spectrophotometric methods (Kojima, Horigane, Yoshida, Nagata, & Nagasawa, 2001; McCarthy, Gonzalez, & McCarthy, 2002; Irie, Horigane, Naito, Motoi, & Yoshida, 2004; Kojima, Horigane, Nakajima, Yoshida, & Nagasawa, 2004; Horigane et al., 2006; Ogawa & Adachi, 2014). Reflecting this moisture gradient, the degree of gelatinization is not homogenous in pasta and noodle strands. Starch granules swell and collapse, and the degree of gelatinization is high at the surface after boiling. This produces the characteristic soft texture of pastas and noodles. Conversely, a number of starch granules remain intact at the core, and the degree of gelatinization is low and the texture remains firm (Lai & Hwang, 2004; Sekiyama et al., 2012). Bonomi et al. (2012) used MRI and chemical analysis of proteins to reveal that denaturation and network formation of wheat gluten protein, which was affected by drying temperatures during processing, were related to water penetration during cooking and the texture of pasta after cooking. Irie et al. (2004) and Kojima et al. (2004) used MRI to study moisture distributions in spaghetti and noodles, and quantitated the relationship between local moisture content and textural parameters measured using a mechanical shearing test.

In this study, we evaluated moisture distribution and mechanical properties of two types of dried quick boil spaghetti that exhibited groove closure and moderately firm texture after boiling by MRI and by shearing test, respectively. The results give us the reason why the quick boil spaghettis have acceptable texture for consumers even after short boiling time. The knowledge obtained in this study will contribute to designing of new quick boil pasta products.

2. Materials and methods

2.1. Spaghetti samples

An ordinary type of dried spaghetti (Sample A) without grooves was used as a control, and two types of dried quick boil spaghetti (Samples B and C) were prepared for this study. For preparation of the spaghetti samples, 100 parts of durum semolina (protein content: 12.8 g/100 g) was mixed with 27 parts of water by weight, and the pasta was extruded under high pressure (9.8 MPa) through a die and dried at 70–90 °C for 5–12 h. The cross sections of Samples A – C are shown in Fig. 1. The diameter of Sample A, a standard type spaghetti, was 1.6 mm. Sample B had a V-shaped groove along the strand, and Sample C had three grooves in the shape of a windmill. When the spaghetti samples were boiled, they were put in at least 10 times their weight of boiling water without the addition of salt. Optimum boiling time of each spaghetti sample was determined in sensory evaluation by the pasta developer's group of Nisshin Flour Seifun Group Inc., at which small area of a non hydrated firm part remained within a strand. The optimum boiling time of Sample A was 7 min. Samples B and C were designed to have optimum boiling times of 4 min and 3 min, respectively, and their grooves close at the optimum boiling times.

2.2. MRI measurement

^{1}H MRI was performed using a 7.1 T microimaging system (DRX300WB, Bruker, Karlsruhe, Germany) with a 15 mm birdcage radio frequency (RF) coil and ParaVision imaging software (ver. 3.0.2, Bruker). Two strands of cooked spaghetti were cut into 1-cm lengths, placed on an acrylic plate, and wrapped with polyethylene film. These samples were fixed into a nuclear magnetic resonance (NMR) tube (15 mm, o.d.) and measured using the multi-slice multi-echo pulse program (MSME in the Bruker library) at 21 °C. The repetition time, echo time, number of echoes with a constant interval of 4 ms, field of view, matrix size, and slice thickness were

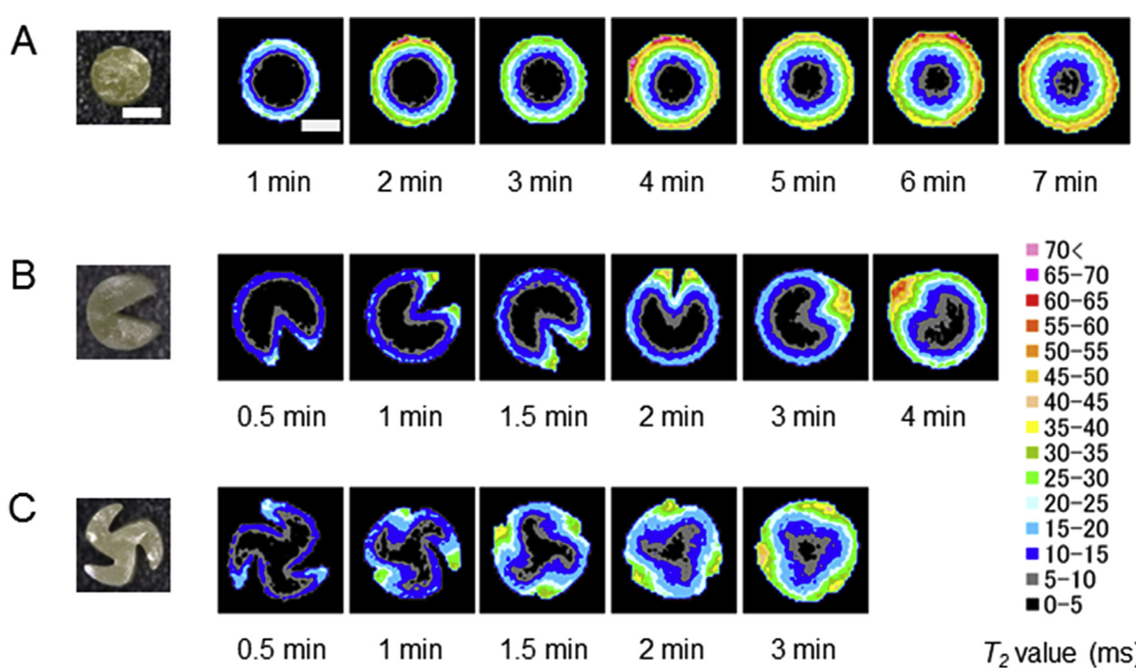

Fig. 1. Cross sectional images of strands of the dried spaghetti samples and changes in the T_2 distribution during the boiling process. A, ordinary round spaghetti; B, quick boil spaghetti with a V-shaped groove; C, quick boil spaghetti with three grooves in a windmill shape. The bar on image A indicates 1 mm.