Effects of Drying Conditions on Moisture Distribution in Rehydrated Spaghetti

Takenobu OGAWA and Shuji ADACHI†

Division of Food Science and Biotechnology, Graduate School of Agriculture, Kyoto University, Sakyo-ku, Kyoto 606-8502, Japan

Received February 1, 2014; Accepted March 13, 2014

†To whom correspondence should be addressed. Fax: +81-75-753-6285; E-mail: adachi@kais.kyoto-u.ac.jp (S. Adachi)

Abstract

Moisture distributions in spaghettis prepared at a maximum temperature of 50, 70, or 85°C, designated as LT-, HT-, or VHT-spaghetti, respectively, and cooked to the average moisture content of 1.71 ± 0.01 kg-H_2O/kg-d.m., were measured. The moisture contents near the surface and at the center of the LT-spaghetti were lower and higher, respectively, than those of HT- and VHT-spaghetti.

Keywords: spaghetti; drying condition; moisture distribution

Pasta made from durum semolina was originally a traditional food in Italy; it is now eaten in many parts of the world. Pasta is generally sold in dried form to improve its storage stability and transportation performance. Originally, pasta was dried at relatively low temperatures. However, drying at high temperatures has now been adopted to shorten the processing time and avoid microbial spoilage. The drying conditions are categorized as low-, high-, and very-high-temperature drying, based on the maximum temperatures of approximately 50, 70, and 85°C, respectively. The spaghettis dried under these conditions are designated LT-, HT-, and VHT-spaghetti. Drying conditions such as temperature affect the quality of dried pasta, including texture, color, and mass loss during cooking. Among these qualities, texture is the most important. Pasta dried at higher temperatures shows higher firmness and lower stickiness after cooking.[1–3] The changes in the texture of pasta dried under different conditions have been explained based mainly on the effects of temperature on protein denaturation and starch properties. The firmness of cooked pasta is related to the strength of the gluten network near the center, and thermal denaturation of gluten at higher temperatures strengthens the network, resulting in increased firmness. Leakage of amylose to the surface layer affects the stickiness of cooked pasta. A decrease in starch damage, resulting from thermal denaturation of amylase, suppresses amylose release, and lowers the stickiness of pasta. The state termed *al dente* is considered to be the best condition of cooked pasta for eating. In this state, the moisture content is low at the center and high near the surface.

We previously reported the rehydration kinetics of LT-, HT-, and VHT-spaghetti, and showed that spaghettis dried at higher temperatures took longer times to reach specific moisture contents.[4] This suggested that the moisture distribution within spaghetti depended on the drying conditions as well as the texture. However, the effect of drying conditions on the moisture distribution has not been elucidated.

In a previous study, we developed a new method for measuring transient changes in the moisture distribution in pasta, using a digital camera, to understand the mechanism controlling water migration in pasta during rehydration.[5] This method was based on increases in the brightness of the sample color with increasing moisture content. The method enabled us to measure lower moisture contents at higher spatial resolutions than other currently used methods, such as magnetic resonance imaging.

In this study, the radial moisture distributions in spaghettis prepared under three different conditions were measured using our method to investigate the effects of the moisture distribution in rehydrated spaghettis on the texture.

Three types of spaghetti, which were processed under different drying conditions, were supplied by the Nisshin Foods Co., Ltd. (Tokyo, Japan). The drying durations for the LT-, HT-, and VHT-spaghetti were 20, 11, and 6 h, respectively. The initial diameters of the spaghettis were about 1.6 mm, and were exactly measured for each sample.

The spaghettis were rehydrated as described in our previous work.[4,6,7] Culture tubes containing about 50 cm^3 of distilled water were equilibrated at 100°C in a stainless-steel tray on a digital hot plate (DP-1S, As One, Osaka, Japan). A sample of length 8 cm was immersed in a tube. At a given time (shown later), the sample was removed from the tube, immediately blotted to remove any superficial water, and weighed, W_1. The samples were dried in a convection drying oven (DO-300FA, As One) at 135°C for 5 h and weighed, W_0. The moisture content of the spaghetti, X_t, was calculated using Eq. (1).

$$X_t = (W_1 - W_0)/W_0 \qquad (1)$$

The moisture distributions of the LT-, HT-, and VHT-spaghetti immersed for 9.5, 9.8, and 10.2 min, respectively, were measured using the method described in our previous work.[5)] The measurement method is based on the increase in the sample color brightness with increasing moisture content. The measurements were repeated three times to check the reproducibility.

Our method for measuring the moisture distribution requires a calibration curve that relates the gray level of the digital image to the moisture content. The calibration curve was prepared using spaghettis rehydrated for different durations (1 to 35 min) with different homogeneous moisture contents (Fig. 1). For all the spaghettis, the gray level became higher with increasing moisture content. A high gray level indicates a light color. The differences in color among the samples were small at low moisture contents, but gradually became larger with increasing moisture content. At a certain moisture content, the spaghetti dried at the highest temperature had the lowest gray level, that is, the color was darkest. Drying at high temperatures promotes the Maillard reaction, which produces melanoidin and facilitates browning.[1,8)] These results were consistent with the calibration curves for the three samples.

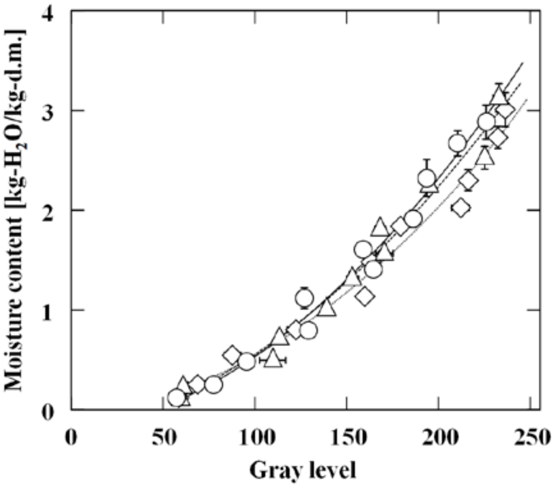

Fig. 1. Relationships between moisture content and gray level for LT-spaghetti (···◇···), HT-spaghetti (--△--), and VHT-spaghetti (—○—) with homogeneous moisture distributions. Bars indicate standard deviation. VHT-spaghetti results were taken from our previous work.[5)]

Figure 2 shows the moisture distributions in the three spaghettis cooked to the *al dente* state. The average moisture content of all the samples was 1.71 ± 0.01 kg-H_2O/kg-d.m. The moisture distribution in the VHT-spaghetti was almost the same as that of HT-spaghetti, but the distribution in LT-spaghetti was different from those in HT- and VHT-spaghetti. The moisture content of the LT-spaghetti was lower near the surface and higher at the center than those of HT- and VHT-spaghetti. We supposed that the water migration mechanism was the same for pastas of

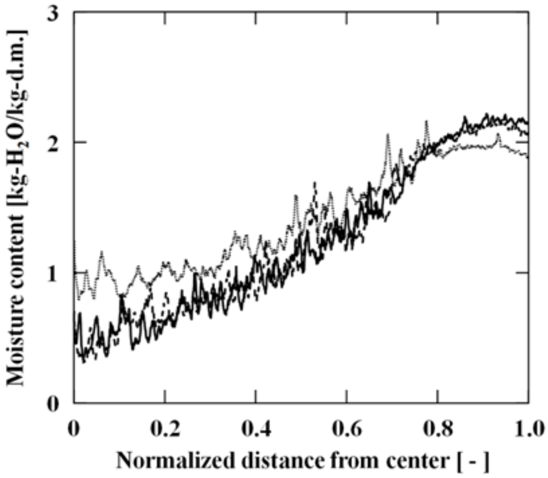

Fig. 2. Moisture distributions in LT-spaghetti (···), HT-spaghetti (--), and VHT- spaghetti (—). VHT-spaghetti results were taken from our previous work.[5)]

different shapes and dried under different conditions, and that diffusion of water was the predominant mechanism for moisture migration near the center, but loosening of the gluten network controlled moisture migration near the surface.[5] Because amylase inactivation is slow during drying at low temperatures, starch is damaged by the enzyme and its gelatinization temperature is lowered.[9] Starch with a low gelatinization temperature is prone to sorb more water, and the apparent diffusivity of water in the spaghetti becomes high. For these reasons, water easily migrates into the spaghetti to produce a relatively flat moisture distribution. Starch granules are embedded in a gluten network in pasta, and the network controls the swelling of the granules by gelatinization, which is a rapid process. Weak thermal denaturation of gluten does not form a sufficiently strong network.[1] This suggests that starch granules embedded in the gluten network swell easily in LT-spaghetti. However, the moisture content near the surface of LT-spaghetti was lower than those of HT- and VHT-spaghetti.

Pasta dried at high temperatures has high firmness and low stickiness.[1,3] It has been suggested that the firmness of pasta is related to the strength of the gluten network at its center. However, the moisture content at the center of LT-spaghetti was higher than those for HT- and VHT-spaghetti. The firmness was therefore ascribed not only to the strength of the gluten network but also to the moisture content at the center. However, stickiness is thought to be caused by leakage of amylose to the surface layer of the spaghetti. The moisture contents of HT- and VHT-spaghetti were higher near the surface than that of LT-spaghetti. Although their high moisture contents suggest that HT- and VHT-spaghetti should be stickier than LT-spaghetti, the opposite tendency is seen because of the suppression of amylose leakage by the strong gluten network formed at high temperatures.[10]

In conclusion, the moisture distributions in the LT-, HT-, and VHT-spaghetti cooked to the *al dente* state were measured. The LT-spaghetti had lower and higher moisture contents near the surface and at the center, respectively, than the HT- and VHT-spaghetti did. The moisture distribution in the LT-spaghetti was ascribed to rapid migration of water in the spaghetti as a result of easy rehydration of damaged starch granules. The low moisture contents at the centers of the HT- and VHT-spaghetti cause firmness, but the high moisture contents near the surface do not seem to affect their stickiness. This study indicated that the quality and texture of pasta could be controlled by the drying conditions.

Acknowledgments

This study was carried out as part of a project by the Cereal Science Consortium of the Graduate School of Agriculture, Kyoto University and the Nisshin Seifun Group, Inc. This study was also supported by a grant from the Japan Society for the Promotion of Science for a research fellow (T.O.).

References

1) Zweifel C, Handschin S, Escher F, and Conde-Petit B, *Cereal Chem.*, **80**, 159–167 (2003).
2) Aktan B and Khan K, *Cereal Chem.*, **69**, 288–295 (1992).
3) Dexter JE, Matsuo RR, and Morgan BC, *J. Food Sci.*, **46**, 1741–1746 (1981).
4) Aimoto U, Ogawa T, and Adachi S, *Food Sci. Technol. Res.*, **19**, 17–22 (2013).
5) Ogawa T and Adachi S, *Food Bioprocess. Technol.*, in press (2013).
6) Ogawa T, Kobayashi T, and Adachi S, *Food Bioprod. Process.*, **89**, 135–141 (2011).
7) Ogawa T and Adachi S, *Biosci. Biotechnol. Biochem.*, **77**, 249–252 (2013).
8) Acquistucci R, *LWT – Food Sci. Technol.*, **33**, 48–52 (2000).
9) Yue P, Rayas-Duarte P, and Elias E, *Cereal Chem.*, **76**, 541–547 (1999).
10) Resmini P and Pagani MA, *Food Microstruct.*, **2**, 1–12 (1983).