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Reducing the Oil Content of Fried Noodles through Forming a Rough and Coarse Gluten Network

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Abstract

Instant noodles have been spreading worldwide. The frying process not only enables high productivity but also provides easy-to-eat property and favorable roast and savory flavor. Although a reduction in the amount of oil in fried noodles is required occasionally, the relationship between oil content and the gluten network in fried noodles has been little studied. The present study aimed to clarify how differences in the density of the gluten network structure can affect the oil content of the fried noodle. In conventional methods for producing fried noodles, the noodle sheet is made from dough using a rolling-press followed by repeated compressions to gradually reduce the thickness to obtain the final rolled noodle sheet. Using electron microscopy, a dense and well-dispersed gluten network was observed in the conventional fried noodle. In contrast, a coarse and roughly-dispersed gluten network structure was observed in noodle sheets formed by extrusion followed by an immediate rapid compression using a rolling-press. This process reduced the oil content of the fried noodles by approximately two-thirds compared with that of the conventionally processed fried noodles with dense gluten. Therefore, this improved process of noodle sheet formation and rolling-press can suppress the formation of the gluten network and so substantially reduce the oil content of these fried noodles made from coarse gluten.

Keywords: Instant fried noodle; Gluten; Oil content; Extrusion process; Rolling press process

Introduction

Wheat, as one of the most widely-consumed crops, can be converted into a variety of processed foods such as noodles [1]. In Asian countries, wheat is often eaten in the form of noodles and in Western countries as pasta. Noodles are made from dough of wheat flour mixed with water during which the conjugation of gliadin and glutenin, as the main components of wheat proteins, forms a gluten network structure. The formation of the gluten network influences dough properties such as elasticity and viscosity [2-7]. In noodles, the gluten network affects the viscoelasticity of the dough and determines the quality of the end-product [6-13]. In conventional methods for producing fried noodles, the noodle sheet is made from dough using a rolling-press followed by repeated compressions to gradually reduce the thickness to obtain the final rolled noodle sheet with a dense and well-dispersed gluten network. Thus, wheat gluten plays an important role in processing these types of food. Instant noodles have been spreading worldwide. Deep-frying is performed in a very short time to provide hygienic and long-life products at a low cost. They can be eaten shortly after adding hot water, and have the desirable roast and savory flavors formed during frying [14-18]. These flavors are popular with consumers but the product is rich in oil with a high calorie content. Recently, especially in developed countries, excessive energy intake has been a health concern [19]. As the consumption of instant noodles has increased, a reduction in the amount of oil in fried noodles is required occasionally.

Several studies on the oil content of fried noodles have been reported. When whole grain flour was used, the oil content of the fried noodles decreased by up to 30% compared with those made from white flour [20]. The wheat cultivar also affected the oil content of the fried noodle and the dough development time during noodle making was negatively correlated with oil uptake [21]. Conversely, oil content has been found to increase as the dough mixing time increased [22]. Thus, as the noodle goes through these processes, the quality of the end product is affected by many factors. However, no report has yet directly investigated the relationship between the structure of the dough gluten network and the oil content of the fried noodle.

This study aims to reveal how the oil content of fried noodles is affected by the formation of the gluten network during their production. In particular, we will investigate how the formation of the noodle sheets and the rolling-press process affects the density of the gluten network and the oil content of the fried noodle. Overall, we propose a new method for producing fried noodles with a lower oil content through improving the conventional production method by changing the formation and the rolling press processes for producing noodle sheet. Although some reports on regulating the oil content of instant noodles are available [21,23], our method aims to improve the control of the oil content of fried noodles produced on an industrial scale.

Materials and Methods

The preparation of samples is shown as a flow sheet in Figure 1. Procedure E is a standard procedure.

Materials

The ingredients used in this study were an all-purpose semi-strong wheat flour (protein content: 11.0%, ash content: 0.42%, moisture content: 14.0%), tapioca starch (ash content: 0.35%, moisture content: 13.5%), dietary sodium chloride, polyphosphate (main component: sodium polyphosphate), *Kansui* (main ingredients: sodium carbonate and potassium carbonate), monosodium glutamate, soy sauce, and meat extract. All ingredients were commercially purchased.

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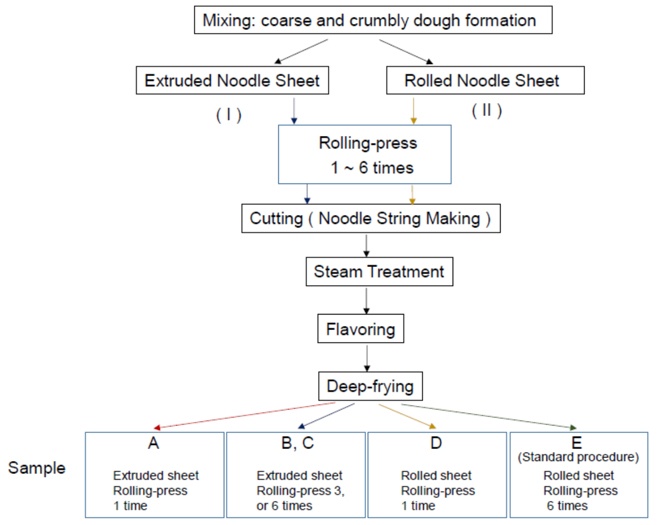

Figure 1: Schematic representation of sample preparation.

Noodle preparation

Mixing: A slurry was prepared by dissolving dietary sodium chloride (15 g), *Kansui* (2.3 g), and polymeric phosphate (0.4 g) in water to a total volume of 340 mL. Coarse and crumbly dough was prepared by adding the slurry to a mixture of semi-strong wheat flour (900 g) and tapioca starch (100 g).

Noodle sheet formation:

Preparation of extruded noodle sheets: Noodle sheets, 9.0 mm thick, were prepared using a noodle extruder. The prepared dough was extruded through a rectangular hole (230 × 7 mm) at a feed rate of 360 g/ min. These products are referred to as "extruded noodle sheets".

Preparation of compound rolled noodle sheets: Coarse noodle sheets were prepared using a forming roller from the same dough as prepared above. Pairs of coarse noodle sheets were pressed together using a compound roller to create a 9.0-mm-thick noodle sheet. These products are referred to as "rolled noodle sheets".

Rolling-press: The noodle sheets were rolled between 1 and 6 times, yielding sheets with a final thickness of 1 mm.

Extruded noodle sheets: Three treatments of extruded noodle sheets (A, B, and C) were prepared, differing in the number of times they were rolled (1–6 times).

A: Extruded noodle sheets were rolled once, compressing them from a thickness of 9.0 mm to 1.0 mm.

B: Extruded noodle sheets were rolled 3 times, compressing them stepwise from a thickness of 9.0 mm to 2.0 mm, to 1.5 mm and then to 1.0 mm.

C: Extruded noodle sheets were rolled 6 times, compressing them stepwise from a thickness of 9.0 mm to 4.0 mm, to 3.0 mm, to 2.5 mm, to 2.0 mm, to 1.5 mm and then to 1.0 mm.

Rolled noodle sheets: Two treatments of rolled noodle sheets (D and E) were prepared, differing in the number of times they were rolled (1-6 times).

D: Rolled noodle sheets were rolled once, compressing them from a thickness of 9.0 mm to 1.0 mm.

E: Rolled noodle sheets were rolled 6 times, compressing them stepwise from a thickness of 9.0 mm to 4.0 mm, to 3.0 mm, to 2.5 mm, to 2.0 mm, to 1.5 mm and then to 1.0 mm.

Cutting: All noodle sheets were compressed to 1.0 mm in thickness by the rolling-press then cut into strings using a square noodle cutter (1.5 mm pitch). These products are referred to as "raw cut noodle strings".

Steam treatment: The raw cut noodle strings were placed in a preheated (100°C) chamber filled with steam at atmospheric pressure then cooked for 2 min.

Flavoring: After steam treatment, the noodle strings were immersed for 5 secs in a flavoring solution (60°C) containing dietary sodium chloride (90 g/L), monosodium glutamate (13.5 g/L), soy sauce (10 mL/L), and meat extract (30 g/L).

Deep-frying and drying: After the flavoring treatment, the noodle strings were dried by deep-frying them in palm oil for 150 secs at around 150°C to evaporate the water, giving a final water content of approximately 2.0 %.

Evaluation of fried noodles

Oil content: The oil content of the samples was measured by the Soxhlet extraction using diethyl ether.

Electron microscopic observations of noodle sheets, raw cut noodle strings, and fried noodle strings: The samples of noodle sheets and raw noodle strings were fixed in formalin solution then treated with α-amylase. Their cross-sectional structures were observed using an electron microscope at 400× and 60× magnification (JCM-6000; JEOL, Tokyo, Japan). The fried noodle strings were de-oiled using acetone. Their cross-sectional structures were observed using an electron microscope at 60× magnification (JSM-6380LA; JEOL).

Viscoelasticity of raw cut noodle strings: Raw cut noodle strings were stretched at a speed of 200 mm/min using a texture analyzer (EZ-Test EZ-S; Shimadzu, Kyoto, Japan) until they broke apart. Their elongation (i.e., displacement at the breaking point) and tensile strength (i.e., test force at maximum elongation) were measured. Eight replications were performed for each sample treatment.

Cross-sectional area, void number, and void ratio: The cross-sectional area of the fried noodle strings was determined by processing their electron microscopy images. The void number and total void area were calculated only from those voids with an area of 100 μm^2 or more. The void ratio was calculated from the total void area and cross-sectional area of the fried noodle strings.

Distribution of oil in the cross-section of the fried noodles: The oil distribution was measured from the cross-sectional images using a Fourier transform infrared (FT-IR) microscopy imaging system (Spotlight400-Spectrum400; resolution, 16 cm^{-1}; scan count, 2; Perkin Elmer, Waltham, MA, USA).

Starch gelatinization in noodle strings due to steam processing: The noodle strings were de-oiled and dehydrated using ethanol and acetone. The degree of gelatinization was then measured using the procedures described by Kainuma et al. [24].

Results

Oil content of fried noodles

Five kinds of fried noodles (A to E) were prepared according to the

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procedures shown in Figure 1. The oil contents after the A, B, C, D and E treatments were 11.4, 14.6, 14.5, 13.0 and 17.2%, respectively (Table 1), the highest being E, and the lowest A.

Gluten network formation

Gluten networks in the formation process of noodle sheets: The extruded noodle sheets exhibited a porous mesh structure, with the gluten network formed being loosely dispersed. In contrast, in the rolled noodle sheets, the gluten networks formed were dense and fine (Figure 2).

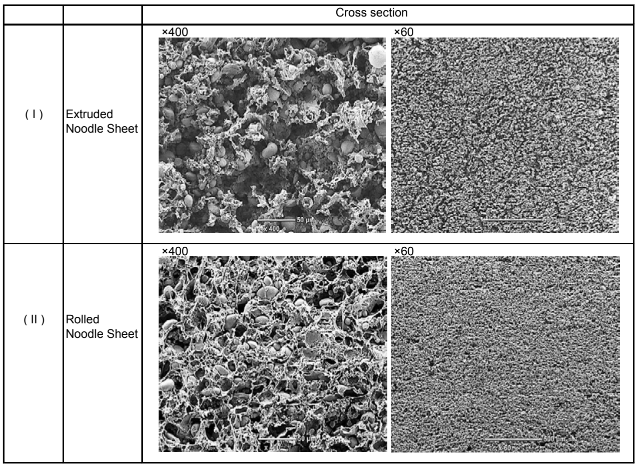

Figure 2: Scanning electron microscope of cross-section of noodle sheets produced by extruder (I) and roller (II).

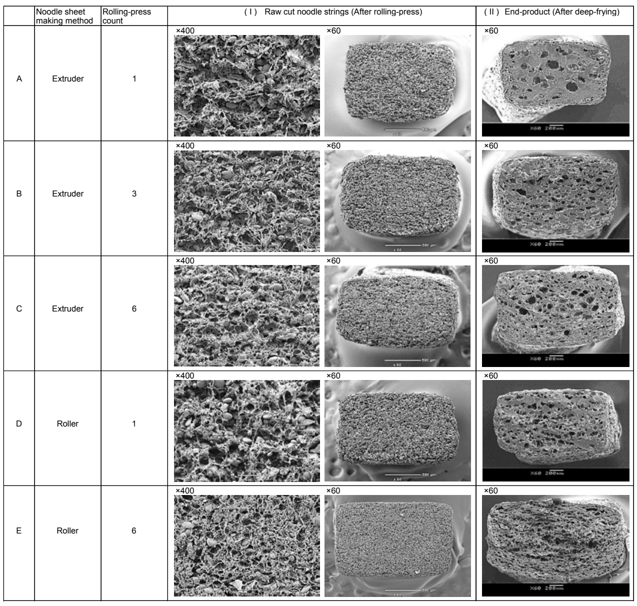

Figure 3: Scanning electron microscope of cross-section of raw cut noodle strings (I) and end-products (II).

Gluten networks in raw cut noodle strings: Electron micrographs of the cross sections of the raw cut noodle strings are shown in Figure 3. Large differences in the density of the gluten network formed in the raw cut noodles were observed between treatments A and E with the former exhibiting a coarse structure and the latter a dense structure. The viscoelastic properties of the raw cut noodle strings were evaluated to assess gluten formation (Figure 4). For treatment E, the elongation of the noodle strings was approximately 80 mm at the break point, in contrast to that from treatment A, approximately 25 mm at the break point. The tensile strengths at the breaking points for these raw cut noodle strings were 0.12 and 0.08 N, respectively. The gluten in the cut noodle strings from treatment E was thus demonstrated to be tougher and more resilient because a greater amount of force was required for it to break. The oil content of the fried noodles from treatment A (coarse gluten network structure) was much reduced compared with that from treatment E (dense gluten network structure), leading to the conclusion that oil content can be reduced by preventing the formation of the gluten network. This also demonstrated that the formation of the gluten network can be suppressed by rolling the noodles rapidly a small number of times.

Characteristics of fried noodles

The end-products from the raw cut noodle strings subjected to the preparation treatments A to E were produced through treatment by steam, flavoring, and frying. For these end-products, the cross-sectional areas, void numbers, and void areas were measured and the void ratio calculated (Table 1 and Figure 3). The samples were ranked by increasing cross-sectional area and total void area as follows: A < D < B < C < E. Ranking by increasing void number was almost identical: A < D < (B, C) < E. The increasing void ratio was also ranked as A < D < B < C < E. For all factors, the minimum values were exhibited by noodles from treatment A, and the maximum from treatment E. This showed that the gluten networks formed in extruded noodle sheets rolled once were coarse and roughly dispersed, resulting in fewer voids and a smaller void area because of the loss of water from dehydration during the frying step.

In terms of the oil content of the fried noodles measured by FT-IR, the samples were ranked as follows in ascending order: A < D < (B, C) < E. The oil was evenly distributed throughout the fried noodles from treatment E, which corresponded with the high number and volume of voids shown in the cross-sectional images (Figure 5). The oil distribution agreed well with the oil content of these samples (Table 1). Fried noodle strings from treatment A exhibited the lowest oil content and the sparsest oil distribution. The degree of gelatinization measured in the noodle strings from the A and E treatments after the steaming and before the frying steps were almost the same (63.7 ± 0.7% and 64.3 ± 1.3%, respectively).

Discussion

In the present study, the relationship between gluten formation

Sample	Sheet making method	Rolling-press count	Oil content (%)	Cross-sectional area (μm^2) × 10^6	Total void area (μm^2) × 10^5	Void number	Void ratio (%)
A	Extruder	1	11.4	1.49	1.62	153	10.9
B	Extruder	3	14.6	1.74	2.80	354	16.1
C	Extruder	6	14.5	1.79	3.29	352	18.4
D	Roller	1	13.0	1.59	2.31	276	14.6
E	Roller	6	17.2	2.18	6.08	636	27.9

Table 1: Characterization of fried-noodles made by different procedures.

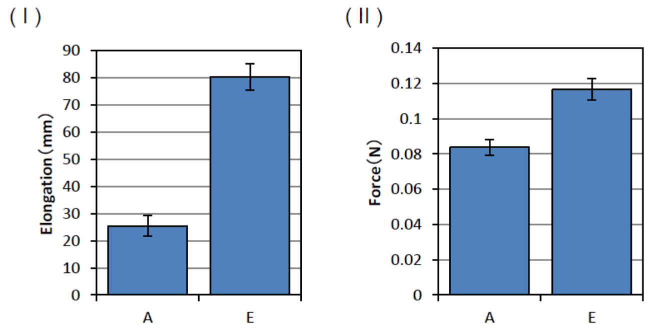

Figure 4: Viscoelasticity of raw cut noodle strings (I; elongation at the breaking points, II; tensile strengths at the breaking points). The data were obtained from each 8 trials (means ± SD).

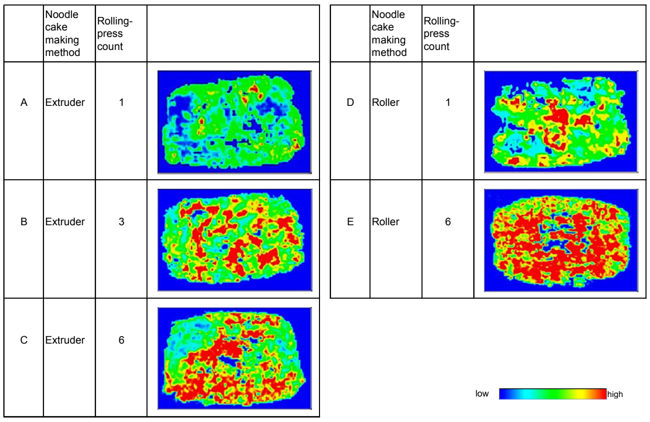

Figure 5: FT-IR imaging of fried noodles. Oil distribution of fried noodles are shown (Samples A-E correspond to Figure 1).

and oil content in fried noodles has been elucidated, demonstrating for the first time that oil content can be reduced by decreasing the density of the gluten network within the noodles. One way of achieving this involves forming a noodle sheet using an extruder then rolling rapidly with fewer rolling actions than in conventional methods.

The properties of the dough and the quality of the fried noodles are both affected by how the noodle sheets are formed and rolled. The rolling of the raw blocks of dough, followed by the elongation of the noodle sheets through roll pressing accelerated the formation of the gluten network. This finding was also supported by the observation of the noodle cross sections using scanning electron microscopy. In samples from treatment E, which exhibited a dense gluten network structure, the noodle strings expanded during frying, causing their cross-sectional area and porosity to increase, with a proportional increase in oil content. In contrast, samples from treatment A, which exhibited a coarse and rough-dispersed gluten network structure, the expansion of the noodle strings was suppressed and their cross-sectional area and porosity decreased, resulting in a reduced oil content. Gelatinized starch granules were also dispersed throughout the gluten network in the noodles before frying. The moisture contained in these gelatinized starch granules evaporated because of the high temperatures used during frying, so that the spaces within the noodles previously occupied by this moisture were then partially filled by oil. Thus, it appears that noodle strings with a coarse and roughly-dispersed gluten network structure contain comparatively less oil as a result of the reductions in cross-sectional area and porosity.

The oil content of noodles can be affected by the level of starch gelatinization [25]. However, we have observed that there was no difference in the degree of gelatinization between noodles from treatment A and the other treatments, indicating that gelatinization did not affect its oil content. Therefore, the reason for noodles after treatment A containing less oil was caused by their poor gluten networks. During conventional noodle making, the dough is mixed thoroughly to ensure the sufficient formation of gluten networks [12,13,26,27] because a well-developed dough with good extensibility is preferred for the noodle-making process. Well-developed gluten networks provide noodles with their characteristic “chewy” texture but generally, the high priority for consumers using instant noodles is that they can eat them (with soup) very quickly after rehydration. Although the gluten network structure of noodles after A and B treatments was coarser than the usual products, in general, the former were not inferior in taste or texture to the latter. These results have indicated that this new procedure for preparing instant noodles at an industrial level can reduce their oil content by combining extruded noodle sheet formation with minimizing the number of rolling-press actions.

Conclusion

This study has confirmed that fried noodles with a coarse and roughly-dispersed gluten network contain a lower oil content than the usual type through examining the relationship between the oil content and the gluten network structure of the fried noodles. In addition, combining extruded noodle sheets with minimizing the number of rolling press actions can be proposed as a specific method for suppressing the formation of the gluten network. This will help to reduce the calorific value of instant noodles.

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