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Design a steam chamber to avoid over gelatinization thus producing straight and single form of rice noodles strings

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Abstract

Over gelatinization of extruded rice noodles during open wet steam cooking is a major problem in the food processing industry and occurs due to the condensation of water droplets that come into contact with noodle strings during the steaming process. This issue may arise due to the presence of stuck noodles in the finished product. Therefore, 5 prototype designs; wooden frame enclosed with polythene sheet (A), wooden frame enclosed with gray cloth (B), wooden frame enclosed with a plywood sheet with two steam inlets in the galvanized door (C), wooden frame enclosed with plywood sheet with multiple steam inlets in the galvanized door (D), and completely enclosed galvanized chamber were made (E). All steam chambers had multiple steam inlets in lateral walls except the chamber with gray cloth. Red rice noodles were prepared from the combination (16% w/w moisture, 200 μm, water at ambient temperature (30±2℃), control atmosphere, 20 min) and fed into five different types of prototype designs to complete the cooking (gelatinization) process. The performance of the five prototype designs was evaluated in terms of the percentage of dried noodles coming out of each design in a single straight form. According to the results, the percentage of dried noodles coming out of each design was (A-50.0±7.1%, B-15.0±5.0%, C-15.0±5.0%, D-50.0±7.1%, E-77.5±4.3% w/w) analyzed. The mean values of all designs revealed that the effective prototype design was "design E" (steam chamber consisted of a completely enclosed galvanized chamber with multiple steam inlets in the two lateral sides). It was able to produce a higher percentage of straight single noodles when compared to other designs. In conclusion, design E is the effective steam chamber to produce straight single rice noodles for the market. The design of a steam chamber is also a very important aspect to avoid over gelatinization thus producing straight and single form of rice noodles strings.

Keywords: rice noodles, over-gelatinization, steam chamber, straight single noodles

Introduction

Rice is one of the most common staple foods in the world and rice noodles are consumed for their texture, taste, and easy preparation process (Gatade and Sahoo, 2015). With developing technology, interest in rice-based products and their production techniques has also increased. Rice noodles are gluten-free food types (Yalcin and Basman, 2008). Therefore, the production of rice noodles is one of the most important aspects of today's food processing industry of Sri Lanka.

In the noodles production process, the steaming process is carried out. The steaming process of the noodles is facilitated to surface gelatinization during noodles preparation. Steam includes gelatinization of starch before drying the noodles. This process improves the water uptake capacity of noodles (Fu, 2008; Yalcin and Basman, 2008). During steaming, starch gelatinization and protein denaturation take place in wet raw noodles. It depends upon the original water, pressure, temperature of the steam, and the time the product is exposed to the steaming process (Fari et al., 2011). Moreover, noodles steamed with hot water spraying speed up the starch gelatinization process and are stopped by washing with cold water. The steam process is critical for noodle cooking and affects to the quality of noodles. Under steam, noodles are hard inside and cause problems in subsequent processing such as stir-frying before serving. While over steamed noodles are sticky and soft (Fu, 2008). Therefore, an optimum steaming

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process is a critical factor to produce good quality rice noodles (Fari et al., 2011).

The rice grains are also affected by the quality of the noodles. The quality attributes of rice grains are cooking and eating properties, appearance as well as the nutritional value of rice grains (Fasahat et al., 2012). Rice varieties containing high gel consistency, low gelatinization temperature, high amylose concentration is most appropriate for making rice noodles (Kasunmala et al., 2020). Rice protein lack gluten; hence lack the functionality of continuous visco-elastic dough. Rice flour paste changes drastically in viscosity during gelatinization. Rice starch gelatinization is a process that occurs naturally in starch granules is insoluble in cold water (Fari et al., 2011). Moreover, gelatinization takes place in a range of temperatures. This temperature range depends on the method of measurement, starch water ratio, granule type, granule size, and granule composition of the flours (Low et al., 2020).

Noodles' qualities are defined by visual attributes of the uncooked and cooked noodles and the cooking and eating qualities such as the absence of discoloration, high glossiness, and high transparency are important considerations of consumers when purchasing dry starch noodles (Thomas et al., 2014). Fine straight strands, whiteness, translucency, and absence of broken strands contribute to better-priced noodles (Tong et al., 2015). Therefore, the production process of rice noodles is important task in food processing industry.

The possible problem of the preparation of the noodles is open wet steam cooking process results in over gelatinization of extruded rice noodles due to water droplets coming into contact with noodles strings during the steaming process. Moreover, over gelatinization of rice noodles is take place due to the condensation of water droplets on the surface of the noodle’s stings. This issue may arise due to the presence of stuck noodles in the finished product. Therefore, consumer acceptance of rice noodles is also reduced. Due to the above problems, the present study was carried out to design a steam chamber to avoid over gelatinization thus producing straight and a single form of rice noodles strings.

Materials and Methods

Design of different types of steam chambers

Five prototype designs were fabricated at the workshop of Harischandra Mills PLC. During fabrication of prototypes, the direction of steam, backfiring of steam flow, area of steam exposed, and pressure heat combination was considered throughout the methods. In order to cope with these situations five (A, B, C, D, and E) prototypes designs were manufactured. Five prototype designs, wooden frame enclosed with a polythene sheet (A), wooden frame enclosed with gray cloth (B), wooden frame enclosed with plywood sheet with two steam inlets in the galvanized door (C), wooden frame enclosed with plywood sheet with multiple steam inlets in the galvanized door (D), and completely enclosed galvanized chamber were made (E) was designed.

Design A (wooden frame enclosed with polythene sheet)

Design A was a completely enclosed wooden frame with a thick Low-Density Polyethylene (LDPE) sheet. The size of the chamber was 62×20.5×27.5 cm^3. A substantial number of steam holes (20–30 pinholes) were present over the lateral side of the polythene sheet.

Design B (wooden frame enclosed with gray cloth)

Design B was a completely enclosed wooden frame with gray cloth. The size of the chamber was 63×41.5×39 cm^3. In here steam holes were not designed.

Design C (wooden frame enclosed with plywood sheet with two steam inlets in the galvanized door)

Design C was a completely enclosed wooden frame with perforated plywood sheet with movable sliding galvanized door. The size of the chamber was 63×41.5×39 cm^3. The number of steam inlets present on the lateral side of the steam chamber was 9 (vertical) and 12 (horizontal). The sliding door also contained two steaming inlets (radius 3 cm).

Design D (wooden frame enclosed with plywood sheet with multiple steam inlets in the galvanized door)

Design D was a completely enclosed wooden frame with perforated plywood sheet with movable sliding galvanized door. The size of the chamber was 63×41.5×39 cm^3. The number of the steaming inlets present on the lateral side of the steam chamber were 9 (vertical) and 12 (horizontal) and the sliding door also contained 7 (vertical) and 9 (horizontal) multiple steaming inlets.

Design E (completely enclosed galvanized chamber)

Design E was a completely enclosed galvanized chamber with a side open galvanized door. Sized of the chamber was 132.1×73.7×91.44 cm^3 and fixed 4 caster wheel lateral sides for easily moveable. The number of the steaming inlets present on the lateral side of the steam chamber were 9 (vertical) and 3 (horizontal) and all surfaces of the chamber are completely sealed.

Design of steel trolley

Steel trollies were used to place the noodles into the steam chambers. A steel trolley was fabricated to place the trays with extruded noodles and also to be fed the trays into the steaming chamber.

Preparation of rice noodles

Cleaned raw red rice (50 kg) was obtained and divided into two equal portions and the moisture content of each was adjusted to 16%. Thereafter, raw rice at 16% moisture content was ground to obtained particle size 200 μm using the pin mill (Kolloplex250z/Mill Power Tech, Tainan city, Taiwan). Rice flour obtained from milling processes was dissolved in water at ambient temperature (30±2℃). Prepared batter with cold water (30±2℃) was kept for 60 min, respectively, for hydration of starch granules. The batter portions were subjected to the extrusion process using a factory-fabricated Rice noodles extruder (Noodle cutter/HML, Matara, Sri Lanka) while maintaining an extrusion temperature of 90℃-95℃. The extruded noodles were collected onto the aluminum trays (Fig. 1).

Evaluation of performance of the five photo types

Red rice noodles were prepared from the best combination and fed into five different types of prototype designs to complete the cooking (gelatinization) process. Performances of the designs were evaluated in terms of degree of over cooking, which is depicted by the stuck noodles in finished product. Therefore, the percentage (% w/w) of cooked noodles coming out of each steaming chamber as single straight forms was categorized as the best steam chamber.

Statistical analysis

The data were reported as mean±SD of triplicates of the experiment. String Separatability were analyzed using One Way Analysis of Variance (ANOVA test) with 95% confidence level ($p<0.05$ significant level).

Fig. 1. Extruding rice noodles on to aluminum trays.

Results and Discussion

Analysis of string separatability of noodles

Red rice noodles were prepared from the best treatment combination (16% w/w moisture content, 200 μm, water at ambient temperature (30±2℃), control atmosphere, 20 min) and fed into five different types of prototype designs to complete the cooking (gelatinization) process. The performance of the five prototype designs was evaluated in terms of the percentage of dried noodles coming out of each design in a single straight form (Fig. 2).

According to the results, prototype A, a completely enclosed wooden frame with a thick LDPE polythene sheet, obtained 50.0±7.1% w/w of string separatability. Furthermore, prototype B, a completely enclosed wooden frame with gray cloth, obtained 15.0±5.0% w/w of string separatability of rice noodles. The prototype C, a completely enclosed wooden frame with perforated plywood sheet with two steam inlets, obtained 15.0±5.0% w/w and the prototype D, a completely enclosed wooden frame with perforated plywood sheet with multiple steam inlets, resulted 50.0±7.1% w/w of string separatability of rice noodles. The prototype E, a completely enclosed galvanized chamber with a side open galvanized door, resulted 77.5±4.3% w/w of string separatability of rice noodles. According to the overall results, the highest string separatability was obtained by prototype E respectively and the mean values of all designs revealed that the effective prototype design was "design E". Because this prototype was able to produce a higher percentage (% w/w) of straight single noodles comparatively other designs. The mean variation of this design (X±SD) is very much less than the other designs. Hence, design E is the best steam

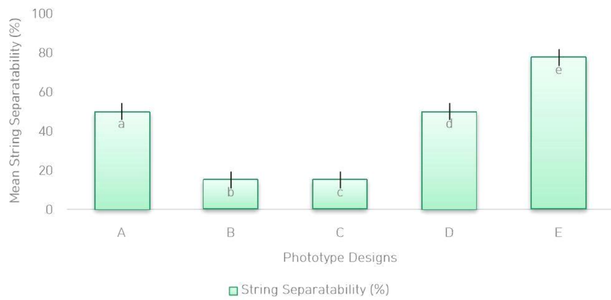

Fig. 2. String separatability of rice noodles in five prototype designs (wooden frame enclosed with polythene sheet (A), wooden frame enclosed with gray cloth (B), wooden frame enclosed with a plywood sheet with two steam inlets in the galvanized door (C), wooden frame enclosed with plywood sheet with multiple steam inlets in the galvanized door (D), and completely enclosed galvanized chamber were made (E). [a–e]Bars accompanied by different superscript represent means that differed significantly by ANOVA test at $p<0.05$.

chamber in order to produce straight single rice noodles for the market. Therefore, the steaming process was significantly ($p<0.05$) affected the string separatability of rice noodles. It is one of the critical factors during rice noodle's processing. The different research studies were investigated the steaming process and quality attributes of the rice noodles and the quality of the final noodles' product is the most important factor to produce the rice noodles (Du et al., 2021; Low et al., 2020). Gulia et al. (2014) also reported the processing, quality, and nutritional aspects of instant noodles. Various research studies were performed to change the production process to reduce the over gelatinization process of rice noodles (Ahmed et al., 2016; Srikaeo et al., 2018). But, there was a lack of research to improve the production techniques related to the food engineering sectors. Therefore, the present study was mainly focused on technological improvement of the noodles processing industry.

Reasons for the best performance of this design

Considering all the production processes of all photo type designs, effective performance was performed by design E. Moreover, wet steaming process, noodles were contacted with water droplets. The noodles were affected by the over gelatinization process due to the condensation of the water droplets on the noodles. Results of the present study revealed that less amount of condensed hot water droplets contacted with the rice noodles during the steaming process. According to the design of the different chambers, there was a steam inlet to maintain the steam flow into the chamber. The steam inlets were controlled the steam flow into contact with noodles. Resulted, the steam inlets were used to limit the contact with noodles and water droplets. According to the five photo type designs, Design E was a completely enclosed galvanized chamber with a side open galvanized door. It consists of the number of the steaming inlets present on the lateral side of the steam chamber were 9 (vertical) and 3 (horizontal) and all surfaces of the chamber were completely sealed. Those steam inlets maintained contact with the noodles and the water droplets. Design E had a low amount of steam inlets compared to other designs. It was most effective to maintain the steam flow. Therefore Design E had effective performance out of four designs when compared with the other designs.

Moreover, the outer casing of design E was fabricated using a galvanized sheet. Therefore the thermal conductivity was comparatively very much higher than the other designs. Thermal conductivity is the heat transferred per unit time and per unit surface area of the chamber (Patel et al., 2016). During the steaming process of noodles, a slight pressure gradient was developed in the steam chamber due to its tightness. Since this design E consists of limited numbers of steam inlet holes. It takes control amount of wet steam which transfers an adequate amount of heat energy through the metal sheet due to high thermal conductivity. Moreover, steam circulation performance in this design was better than the other designs. Design E contains a limited number of steam inlets. Due to that, steam circulation and time period of the steam in the chamber was high compared to other designs. Hence, the condensation of water droplets was effectively reduced. Thus broken noodles strings were effectively reduced due to the overcome of the over gelatinization process. Therefore design E was the effective steam chamber to produce rice noodles.

Conclusion

The present study was performed to produce a steam chamber for rice noodle processing. During the steaming process, over gelatinization was occurred. To reduce the above problems, different types of prototype designs were fabricated. According to the results of string separatability of rice noodles, the best design was design E out of other designs. According to the engineering design of prototype E, water droplets contacted with noodles were effectively reduced during the steaming process. Resulted straight and single forms of noodles were prepared thus reducing over gelatinization of rice noodles.

Conflicts of Interest

The authors declare no potential conflict of interest.

Acknowledgments

Not applicable.

Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

Author Contributions

Conceptualization: Navarathne SB.
Data curation: Shanika MKA.
Formal analysis: Navarathne SB.
Methodology: Kumararathna KS.
Software: Jayamanne VS.
Validation: Jayamanne VS.
Investigation: Jayamanne VS.
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