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Investigation of the Influence of Extrusion Conditions on Cambodian Extruded Rice Vermicelli

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Abstract: *Rice is one of the most important crops used in the production of ready-to-cook (RTC) products such as noodles, rice vermicelli, ready-to-eat (RTE) breakfast cereals, and snacks due to its color, bland taste, and good processing properties. Extrusion is one of the most creative food processing methods that have been used for product development. This technique helps to improve the nutritional, functional, and sensory properties of the products. The extrusion authorizes process control such as mixing, cooking, and product shaping simultaneously. In this study, the extrusion process parameters, including feed moisture rate (24 and 25%), barrel temperature (100 and 110°C), and screw speed (50–80 rpm), were conducted, and the physico-chemical properties and cooking qualities of extruded rice vermicelli were investigated. The results showed that the three parameters had a significant impact on product quality and consumer satisfaction. The pH of the final extruded rice vermicelli ranged from 6.62 to 6.68, while the moisture content ranged from 10.02% to 10.84%, and the water activity (aw) ranged from 0.522 to 0.573. The water absorption index (WAI) and water solubility index (WSI) were in the range of 397.46%–485.85% and 4.83%–6.15%, respectively. Cooking weights varied from 173%–180%, and cooking losses were reported between 12.10% and 17.93%. The extrusion parameter has no impact on pH while affecting aw and moisture levels, which are significantly different from one to another. At any temperature, rice vermicelli extruded at a lower screw speed (50 rpm) showed a relatively higher WAI value than at higher screw speeds (70 and 80 rpm). In contrast, the effect of barrel temperature and screw speed was the opposite of what was seen with WAI. Cooking time had an impact on how much cooking loss is reported in dry rice vermicelli, with longer cooking times leading to greater cooking loss. However, an increase in cooking losses results in a decrease in cooking weight.*

Keywords: Twin-screw extruder; Extruded Rice Vermicelli; Cooking quality, Water absorption index (WAI), Water solubility index (WSI)

1. INTRODUCTION[1]

Rice (Oryza sativa L.), known as Asian or common rice, has two primary eco-geographic races: indica and japonica. Rice has been a precious food in the human diet and may be the food that has fed more people than any other crop in history. Even today, rice grains feed two-thirds of the world's population. In Cambodia, rice is a staple food and accounts for at least 65% of the energy intake in the diet of most Cambodians [1]. Normally, rice is exported in the form of raw materials as milled rice with little or no exports of finished rice products. It is primarily consumed as milled rice, but there is a number of products where rice is added as an ingredient or a raw material for many traditional Khmer foods and beverages, such as rice vermicelli (Num Banh Chok), rice noodles (thick and thin), pin noodle (Lot), rice paper, Banh Hoi, Banh Kanh, wine, snacks, and desserts. In Cambodia, Khmer rice vermicelli is typically produced on a modest, labor-intensive basis with poor sanitation and a low proportion. However, these products were made traditionally, resulting in limited production and lower product quality.

Physico-chemical factors and processing procedures determine the final state of the noodle. Gluten from wheat is mainly responsible for the formation of noodle structure and for the strength of boiled noodles. Rice contains no gluten. Thus, the quality of rice vermicelli is solely determined by the physico-chemical properties of starch, serving as the product's structural [2]. Only the rice with high amylose content could produce instant flat noodles with desirable cooking and textural qualities[3].

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Rice has become a popular ingredient in the extrusion industry due to its bland taste, attractive white color, hypo allergenicity and ease of digestion [4]. Cooking by extrusion is known as a continuous process with a high production capacity, versatility, and low per-unit cost. The traditional way to make rice vermicelli from fermented milled rice causes problems with wastewater disposal and microbiological quality, such as total plate count, total yeast and mold count, lactic acid bacteria, *Enterobacteriaceae*, total coliforms, *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus cereus*. 74% of fermented Khmer rice noodles and 98% of non-fermented Khmer rice noodles were found to be contaminated with all the mentioned bacteria [5]. The direct extrusion of rice vermicelli made from dry rice flour might be able to replace the earlier approach to solving this issue. This could improve the production of rice vermicelli, which is easy to manage and sanitize. To our knowledge, there were very few reports of rice vermicelli being extruded from rice flour. The properties of native flours and starches, which are generally not resistant to the high temperatures and high shear forces involved in the extrusion process, cause a major issue, resulting in rice vermicelli of poor quality [6]. Based on these observations, this research work aimed to investigate the effect of extrusion parameters such as feed moisture rate, barrel temperature, and screw speed on the properties of extruded rice vermicelli. The physico-chemical properties, including pH, moisture content, water activity (a_w), water absorption index (WAI), water solubility index (WSI), and cooking quality of rice vermicelli (cooking time, cooking weight, and cooking loss), were evaluated in this study.

2. METHODOLOGY

2.1 Sample collection and preparation

Numerous rice (*Oryza sativa L.*) samples were collected for testing their amylose content. Nine rice varieties named Neang Menh, Phka Romdoul, Chmar Prum, Phka Knhey, Phka Mlis, Sen Kr Oub, CAR11, and Neang Oum were randomly selected from the four local markets (Phsar Chas, Phsar Leu Thom Tmey, Phsar Deum Krolanh, and Phsar Krom) located in Siem Reap provinces in Cambodia. All collected samples were placed in a sterilized, airtight plastic bag and then transported to the laboratory for analysis of their chemical compositions.

High amylose content rice (CAR11) was selected (Table 2) for further processing in the current study. The rice sample was ground using a fine powder grinder (Model SL30, CW, Thailand) with a sieve of 0.70 mm. All the flour samples were packed in airtight plastic bags and stored at 4 °C until further analysis.

2.2. Extruder and extrusion cooking

The extruded rice vermicelli was produced by a twin-screw extruder (Model: TSE 24 MC: 24 mm-L/D: 40, Thermoscientific, Germany). The length of the twin screws is 960 mm. During extrusion, the extruder was equipped with a digital display for torque (T, %). The extruder had ten-barrel zones and one die zone. The barrel that houses the twin screws has nine-barrel zones (Zone 2–Zone 10) controlled by solenoid valves. Only the first barrel zone is permanently maintained at room temperature, while the other zones are heated. The flour was fed into the extruder inlet port by a screw feeder. Water was injected into the extruder with a water pump to change the feed's moisture level. This experiment was conducted with eight conditions: feed moisture rate (24 and 25%), barrel temperature (100 and 110°C), and screw speed (50–80 rpm). The temperature profiles for the eight conditions from zone 2 to zone 9 were controlled and kept constant at 40, 40, 50, 60, 70, 80, 90, and 100 ºC, whereas in zone 10 and the die zone, temperatures were set between 100 and 110 ºC. A die diameter of 2.98mm was used in this study. The extruded noodles were air-dried at room temperature for 24 hours [7] and later kept in sealed, airtight bags prior to further analysis. The details of the experiment's conditions are summarized in Table 1.

2.3. Amylose content analysis

Amylose content was determined based on iodine-binding [8]. Standard curve was prepared using pure potato amylose. Initially, about 40 mg of potato amylose was accurately weighed in a 100 ml volumetric flask, following by addition of 9 ml of NaOH (1N) and 1 ml of ethanol (95%). The mixed solution was boiled on a boiling water for 15 minutes, cooled and made up to 100 ml with distilled water. After being diluted, a volume of 1 ml, 2 ml, 3 ml, 4 ml, and 5 ml of the solution were poured into five different volumetric flasks with the addition 0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml, and 1 ml of acetic acid (1N) respectively. Afterward, 2 ml of iodine solution (0.2%) was added to the five flasks, topped up to 100ml with distilled water and kept in the dark for 20 min. The absorbance of all standard solutions was measured at wavelength of 620 nm using Cary 60 UV-Visible spectrophotometer (Agilent, USA).

The sample with 100 mg was subjected to the analysis following the same procedure as indicated above. The analysis was carried out in triplicate. The amylose contents in samples were determined by referring to the standard curve (Figure 1).

2.4. Determination of moisture content

The moisture was determined using AOAC methods (2000). Firstly, aluminum plates were oven-dried at 103.5 °C for 1 hour and then stored in a desiccator for 15 minutes and weighed. After that, about 2 g of samples were loaded into the aluminum cups and spread thinly. Then, the aluminum cups with the sample were transferred into an oven that had already been heated. The samples were oven-dried for 3 hours. After drying, the samples on aluminum plates were transferred into the desiccator to cool down to room temperature for 15 minutes. Finally, the samples in aluminum cups were reweighted. Then the moisture content was calculated by following the formula:

$$\%Moisture = [(m_1 - m_2)/m] \times 100 \quad \text{(Eq. 1)}$$

Where,
m = weight of sample (g)
m_1= weight of sample and aluminum cup before dry (g)
m_2= weight of sample and aluminum cup after drying (g)

2.5. Water activity analysis

Water activity (a_w) was determined by using a water activity meter (Model Aqualab 4TE, Germany) at the ambient temperature 25 °C. The water activities plates were dried at 50℃ for 30 min. The instrument was calibrated using distilled water to achieve a water activity of 1.000, then using a saturated NaCl solution to achieve an a_w of 0.7530. Two grams of ground rice vermicelli were weighed and placed into the dish. The measurement of water activity took placed once stabilized.

2.6. pH analysis

The amount of 5g of ground samples was diluted with 45ml of distilled water. The mixture was continuously stirred at the room temperature for 10 minutes for good homogenization. The pH value of each diluted sample was measured by a pH meter (Laqua F-72-Horiba).

2.7 Water absorption index (WAI) and water solubility index (WSI)

The determination of WAI adapted from previous study of Gelencsér et al., (2008). To begin, 2.5 g (dry basis) of ground rice flour sample was suspended in 25 ml of distilled water at the room temperature in a tare 50 ml capacity centrifuge tube with occasional stirring for 30 min and centrifuged at 3000 rpm for 15 min. A known-weight aluminum dish was used to decant the supernatant, which was then dried at 105 °C hot air oven for 12 hours until it reached a constant weight. The tube containing the leftovers was also weighed. WSI stands for the weight of dry solids in the supernatant stated as a percentage of the sample's original weight, and WAI stands for the weight of residue left behind after the supernatant has been removed per unit weight of the original dry solids minus the mass of supernatant evaporation residue, and given equation below:

$$WAI = (W1/ W2) *100 \quad \text{(Eq. 2)}$$
$$WSI = (W3/W2) *100 \quad \text{(Eq. 3)}$$

Where,
W1 = mass of the centrifuge residue (g)
W2 = sample mass (dry basis) (g)
W3 = mass of the supernatant evaporation residue (g)

2.8. Cooking time, cooking weight and cooking loss

Following American Association of Cereal Chemists (AACC) guidelines, cooking duration, cooking weight, and cooking loss were determined in this study. Five grams of extruded rice vermicelli, measuring 5 cm in length, were weighted and cooked in 300 ml of boiling water. The vermicelli strands were drained pressed between two glass plates. The time required for the opaque part of the strand to be gelatinized was considered as cooking time. The cooking weight (%) on a dry basis of 25 grams of dried extruded vermicelli cooked in 300 ml of boiling water at the optimal cooking time until fully cooked. The cooking loss (% dry basis) or weight of total solids lost during cooking was determined by evaporating the dried vermicelli's cooking water to dryness in a hot air oven heated to 100 °C plus 1 °C for twenty hours[6]. The following formula was used to determine the cooking time, cooking weight, and cooking loss:

The following formula was used to determine cooking weight and cooking loss:

$$CW (\%) =(W1\times100)/W \quad \text{(Eq. 4)}$$
$$CL (\%) = (W2 \times100)/W \quad \text{(Eq. 5)}$$

Where,
CW (%): The percentage of cooking weight (% of dry vermicelli),
W1: The weight of the noodle sample after boiling (g) W: The weight of noodle sample (g),
CL (%): The percentage of cooking loss (% of dry noodle),
W2 is the constant weight of filter residue after drying in oven.

2.9. Data analysis

The analysis was performed in triplicate. The gathered data were reported as the mean ± standard deviation and subjected to analysis of variance (ANOVA) with statistical software (SPSS) version 23.0. Significant differences were assessed at p<0.05.

Table 1. Extruding conditions of rice vermicelli

Sample code	Feed Moisture (%)	Temperature of die and screw zone (°C)										Screw speed(rpm)
		Die	Z10	Z9	Z8	Z7	Z6	Z5	Z4	Z3	Z2	
RV-1	25	110	100	100	90	80	70	60	50	40	40	50
RV-2	25	110	100	100	90	80	70	60	50	40	40	60
RV-3	25	110	100	100	90	80	70	60	50	40	40	70
RV-4	25	110	100	100	90	80	70	60	50	40	40	80
RV-5	24	110	110	100	90	80	70	60	50	40	40	50
RV-6	24	110	110	100	90	80	70	60	50	40	40	60
RV-7	24	110	110	100	90	80	70	60	50	40	40	70
RV-8	24	110	110	100	90	80	70	60	50	40	40	80

Feed moisture (%) refers to rice flour and water
rpm refers to a round per minute

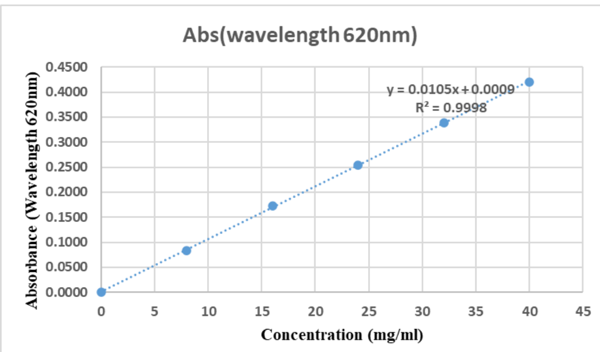

Fig. 1. Amylose standard curve

3. RESULTS AND DISCUSSION

3.1. Chemical composition of rice flour

Amylose content plays an important role in evaluating the cooking, consumption, and pasting properties of rice [10]. Amylose content is the second main component of rice starch. Based on amylose content, rice can be divided into five categories: waxy rice (0–2% amylose), very low rice (2–12%), low rice (12–20%), intermediate rice (20–25%), and high rice (>25%) [11]. Chemical composition of rice flour (CAR11) in the current study was summarized in Table 2. The result showed that CAR 11 has an amylose content of 34.74%, which is a high amylose content that serves as a good raw material for rice vermicelli production. Moisture content also has an effect on amylose content since it determines the final amylose content in rice samples. With a moisture content of 12.51%, it was acceptable with a water activity of 0.5 and a pH of 6.31. There has no affect the quality of the products in terms of microbiological growth. At this rate, most microbes were not able to grow and could not spoil the products [12].

Table 2. Chemical composition of rice flour (CAR11)

Parameter	Value
Moisture (%)	12.51 ± 0.37
Amylose (%)	34.74 ± 0.81
pH	6.31 ± 0.00
a_w	0.54 ± 0.002

3.2. Moisture content, a_w and pH of extruded rice vermicelli

According to Table 3, extruded rice vermicelli's pH did not alter considerably after processing under various conditions, proving that the feed moisture, screw speed, and temperature had no effect on each extruded rice vermicelli's pH ($p>0.05$). From the raw material to the final product, the pH value increases slightly. The pH value of the extrudate varies depending on the type of rice and cooking method. According to a study published in the Journal of Food Science, cooked rice has a pH of 6.0 to 7.2, which is slightly acidic to neutral [13]. It is important to note that the pH of rice vermicelli can be affected by factors such as the type of water used for cooking, the cooking method, and the addition of other ingredients.

Moisture content is a crucial criterion that affects practically every material and food product, notably in terms of quality and shelf life. In Table 3, extruded rice vermicelli has a low moisture content of about 10%, which led to a quick drying process that reduced space and equipment costs [14]. The moisture content ranged from 10.02% to 10.84%, respectively. The highest moisture was 10.84% presented in the sample using high feed moisture, temperature condition, and screw speed at 25%, 110 °C, 100 °C, and 50 rpm, respectively. Feed moisture rate was also affecting the moisture content of rice vermicelli extruded. If the feed was high in moisture content, it also had a high moisture content of the final products. Decreasing feed moisture content or increasing barrel temperature with the higher screw speed lead to reduce the moisture content of extrudates during extrusion. There was a significant interaction between feed moisture content, barrel temperature, and screw speed. These results were acceptable because its moisture content was around 9–12% with an estimated water activity of 0.5. That did not affect the quality of products in terms of microbiological growth [12]. At this rate, most microbes were not able to grow and could not spoil the products.

One of the main factors inhibiting or limiting microbial development is water activity. The a_w is frequently the key factor in defining the type of microbes found in food, controlling microbial response, and ensuring food stability [15]. It affected the rice noodles' texture, spoiling the process, lowering the quality of the rice vermicelli, and reducing shelf life. Too much or too little water activity can cause noodles to become moldy or hard, making it difficult to rehydrate. The values of water activity (a_w) of samples ranged from 0.520±0.005 to 0.573±0.000 (Table 3), which showed a statistically significant difference ($p<0.05$) from each condition. According to the literature, the water activity of the extruded rice vermicelli ranged from 0.5-0.6 [16]. Among the 8 conditions of rice vermicelli extrudate (Table 3), the highest level of water activity was in condition RV1 (0.573±0.00) which is probably due to low temperature at zone 9 and 10 (100 °C) and lowest screw speed (50 rpm). There was no significant difference ($p > 0.05$) between two samples RV1 and RV6, even the temperature at zone 10 and screw speed are slightly different. When the screw speed and barrel temperatures increased, the a_w tended to drop, and it is unaffected by feed moisture rate. In these regards, the extrusion conditions on feed moisture had no significant effect ($p > 0.05$) on the a_w of extruded sample.

Moisture content and water activity have a significant impact on the quality of dry rice vermicelli. If the moisture content is too high, the noodles stick together and accumulate, but if it is too low, they become brittle and break easily [14]. In addition, the rice noodle shelf life can be extended considerably by limiting the biochemical and microbiological stability, which can be achieved by drying the noodle strands to a minimal moisture level [17].

Table 3. Results of pH, moisture content, and a_w of extruded rice vermicelli.

Sample	pH (ns)	Moisture content (%)	Water activity
RV-1	6.62±0.02	10.84±0.17^{de}	0.573±0.000^{c}
RV-2	6.66±0.01	10.77±0.26^{e}	0.558±0.001^{a}
RV-3	6.66±0.03	10.44±0.03^{d}	0.541±0.003^{d}
RV-4	6.66±0.01	10.15±0.45^{b}	0.520±0.005^{e}
RV-5	6.67±0.02	10.40 ±0.35^{a}	0.541±0.003^{b}
RV-6	6.68±0.028	10.32±0.07^{c}	0.532±0.002^{c}
RV-7	6.65±0.01	10.27±0.33^{b}	0.528±0.002^{bc}
RV-8	6.64±0.03	10.02±0.31^{ab}	0.522±0.002^{e}

Different superscript letters in the same column indicate significant differences ($p<0.05$)
ns: not significantly different ($p>0.05$)

3.2. Water absorption index (WAI) and water solubility index (WSI)

The capacity to absorb water would increase as the degree of damaged starch increased. Similar to this, starch granule size also affects how well it can absorb water [18]. Based on Table 4, the results of WAI were found significantly different at ($p<0.05$) and it ranged between 397.46% and 485.64%. The sample RV-4 with screw speed 80 rpm, and feed moisture 25% had the lowest WAI (397.46%), while the sample RV-5 with screw speed 50 rpm, had the highest percent among all the samples with WAI 485.64%. Since the samples of extruded rice vermicelli in this study were made from rice with a high amylose content (34%), their WAI was probably much higher than those with a low amylose content [18]. It was also related to the fact that the product, which is prepared from rice, has a high WAI. This was due to the fact that rice starch has considerably smaller granules than other cereal starches and has a larger surface area for absorbing water [17]. This may be related to the degradation of starch, which causes a reduction in the water-holding capacity of the molecules as a result of a decrease in molecular size. At a low shear rate (low screw speed) and/or low temperature, there are likely to have more unbroken polymer chains and more hydrophilic groups, which can bind more water and make

WAI values higher [7]. At any temperature, samples extruded at a lower screw speed (50 rpm) showed relatively higher WAI values than those from higher screw speeds (70 and 80 rpm). This is perhaps due to the high residence time at low screw speed, which permits an enhanced extent of cooking [17].

The water solubility index (WSI) measures the quantity of solids that dissolve in water, and WSI is also a measure of how the extruded product behaves when it interacts with water during further processing [17]. According to Table 4, the results of the WSI ranged from 4.83% to 6.15% and were significantly different (*p<0.05*) of each condition. The sample RV-1 had the lowest screw speed (50 rpm), resulting the lowest percent of WSI of 4.83%. While the sample RV- (the highest screw speed 80 rpm) was reported with the peak value of WSI at 6.15%. It is noted that, the effect of barrel temperature and screw speed was the opposite of what was seen with WAI [17]. Samples that were extruded at higher barrel temperatures and screw speeds will have high WSI values. The WSI depends on the quantity of soluble of rice vermicelli, which increases due to the degradation of starch. Wen *et al*. (1990) indicated that screw speed had a direct effect on polysaccharide size distribution. Higher screw speeds result in more fractions than lower screw speeds because of the degradation of amylose and amylopectin molecules in starch through chain splitting.

Therefore, it could be inferred that the combined effect of high temperature and high screw speed enhanced the amount of soluble materials in the extrudate [7].

Table 4. Water absorption index (WAI) and water solubility index (WSI)

Sample	WAI (%)	WSI (%)
RV-1	468.85±0.76^{d}	4.83±0.13^{a}
RV-2	441.66±0.49^{c}	4.91±0.17^{b}
RV-3	433.65±0.82^{b}	5.15±0.05^{c}
RV-4	397.46±0.71^{a}	5.26±0.03^{a}
RV-5	485.64±0.65^{g}	4.87±0.03^{a}
RV-6	484.40±0.81^{f}	4.98±0.06^{b}
RV-7	467.80±0.51^{d}	6.09±0.05^{d}
RV-8	477.05±0.82^{e}	6.15±0.09^{d}

Different superscript letters in the same column indicate significant differences (*p*<0.05)

3.3. Cooking quality of extruded rice vermicelli

Rice-based noodles cook faster than wheat-based noodles due to their larger starch granules and smaller surface area for hydration. Higher temperatures result in shorter cooking times and lighter rice noodles, as higher temperatures increase starch gelatinization [20]. The cooking parameters of all rice vermicelli samples are presented in. Table 5. The results of cooking time ranged from 22.42±0.23 to 25.16±0.12 min, which were significantly different (*p*<0.05). Among all the conditions, the sample RV-5 had the shortest cooking time (22.42±0.23min), which was operated at the highest screw speed at 80 rpm, while RV-9 had a lower screw speed of 50 rpm but the same barrel temperature, resulting in the longest cooking time (25.16±0.12) min. This could show that, screw speed had significant effect *(p* > 0.05) on the cooking time while feed moisture and barrel temperature did not. Although, as mentioned by [18], the cooking time for brown rice noodles was 9.86 min, which increased to 13.24 min when the amylose level in the brown rice rose. The amount of amylose content in the rice vermicelli samples affected how long they should be cooked for the cooking times of rice noodles. Furthermore, various starches at different levels in rice flour affected the cooking time and texture of rice-based vermicelli [17]. Additionally, extruded rice vermicelli in this study took 20 to 25 minutes to cook due to their larger surface area for hydration and smaller starch granules. Thin strands cook faster than thick ones due to their easier water dispersal [17].

According to Table 5, the results of cooking weight ranged from 173.54±0.77% to 182.00±0.26% and were significantly different (*p<0.05*). The sample RV-8 with the highest screw speed of 80 rpm and a high barrel temperature at zone 10 and die zone (110,110°C) had the highest value of cooking weight at 180.53±0.86%. In contrast, the sample RV-1 had the smallest value of cooking weight 173.00±0.26% with the lowest screw speed of 50 rpm and a low barrel temperature. When operated with the same feed moisture rate and similarity of screw speed, the extruded samples showed the same value of cooking weight, as it can observed with RV-2 and RV-3. The extruded rice vermicelli's cooking weight value had altered considerably after processing under various conditions, proving that the screw speed and temperature had an effect on each extruded rice vermicelli's cooking weight. The increase in barrel temperature in both zone 10 and the die zone tended to increase cooking weight and reduce cooking loss. The loss in weight of extruded vermicelli during cooking was mostly due to the solubilization of unsightly bound gelatinized starch on the surface of the noodles. That is, the extent of cooking loss would mainly depend on the degree of starch gelatinization and the strength of the gel network-like structure of the noodles [14].

Cooking loss is an important factor influencing the cooking quality of noodles. High cooking loss is undesirable because it indicates starch's high solubility, resulting in murky cooking water, low cooking tolerance, and a sticky texture [21]. The primary cause of weight loss is the starch on the surface of the noodles that has gelatinized, become soluble, and become loosely bonded during cooking. The strength of the gel network within the noodles and the level of starch gelatinization effect this loss [21]. Based on Table 5**,** the results of cooking loss were found significantly different (p<0.05) and ranged between 12.10±0.21% and 17.93±0.05%. The sample RV-6 had the highest cooking loss of all the samples reporting at 17.93±0.05%, while RV-4 had the lowest cooking loss 12.10±0.21%. Longer retrogradation times could increase gel-like network strength, with cooking loss ranging from 6.01% to 7.84% [20]. As expected, the cooking loss showed a negative correlation with solubility (p<0.05). For the extruded rice vermicelli RV-4 operating at barrel temperatures zone 10 and die zone at 100 and 110°C; feed moisture and screw speed at 25% and 80 rpm showed cooking loss at 14.19% dry vermicelli (dry weight basis), which is within the accepted range for commercial vermicelli (less than 12.5% wet weight basis or about 14.2% dry weight basis [6]. According to their studies, the cooking time had an impact on how much cooking loss there was in dry rice vermicelli, with longer cooking times leading to greater cooking loss. Thinner noodles exhibited larger cooking losses than thicker ones, and the thickness of the noodle also influenced the cooking losses [20]. The decrease in cooking weight and increase in cooking loss, however, indicate that excessive cross-linking may reduce the starch's swelling capacity. Lightly to moderately cross-linked products should be considered instead to improve the product's cooking quality without reducing cooking weight. Moreover, the extruded rice vermicelli could be cooked (with or without soaking in water before cooking) as needed for the rice vermicelli obtained from the traditional process. This leads to time savings and user convenience [14].

No significant (p<0.05) changes in noodle size from each different condition of the extrusion (feed moisture, barrel temperature, and screw speed rate) were observed. The diameter of dry rice vermicelli ranged from 3.58–3.64 mm and each vermicelli strand showed a white color, regularity in its size, and a smooth surface.

Table 5. Effect of extruder condition on cooking qualities of extruded rice vermicelli

Sample	Cooking Quality			
	Cooking time (min)	Cooking weight (%)	Cooking loss (%)	Dried vermicelli diameter (mm)^{ns}
RV-1	24.4±0.08^{ef}	173.00±0.26^{ef}	12.10±0.21^{a}	3.61±1.12
RV-2	24.24±0.13^{e}	175.68±0.13^{bc}	12.57±0.34^{a}	3.58±1.48
RV-3	23.56±0.02^{d}	177.45±0.73^{bc}	13.82±0.18^{b}	3.63±1.26
RV-4	22.42±0.23^{b}	178.79±0.47^{cd}	14.19±0.09^{b}	3.59±1.28
RV-5	25.16±0.12^{g}	173.54±0.77^{a}	15.99±0.42^{c}	3.60±1.35
RV-6	24.54±0.06^{f}	176.06±0.56^{b}	16.85±0.13^{cd}	3.59±1.32
RV-7	24.50±0.03^{f}	179.32±0.70^{ab}	16.96±0.35^{d}	3.62±1.29
RV-8	23.16±0.06^{c}	180.53±0.86^{de}	17.93±0.05^{e}	3.64±1.20

Different superscript letters in the same row indicate significant differences (p<0.05)
ns: not significantly different (p>0.05)

4. CONCLUSIONS

In this study, rice with an amylose content of 34.74% was found and used to produce extruded rice vermicelli. The physico-chemical characteristics and qualities of extruded rice vermicelli were significantly influenced by varying feed moisture (24–25%), barrel temperature (100–110°C), and screw speed (50–80 rpm). The extrusion process had significant effects on moisture content, WAI, WSI, cooking time, cooking yield, and cooking loss, respectively (p<0.05). Meanwhile, there is no significant effect on the pH or a_w of the products (p>0.05). The results of the study may provide the basis for the development of rice vermicelli with good qualities and health benefits. For further study, the different types of rice cultivars should be used rather than only high-amylose rice. On the other hand, food additives like modified starch and emulsifiers should be used to improve the quality of rice vermicelli.

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