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Physico-chemical Characteristics of Rice-based Cereal Processed by Twin-screw Extrusion and Microwave Cooking

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Abstract: *Rice is one of the most frequently utilized ingredients in extruded snacks and cereals because of its wide availability and high expansion capability. To promote exports of rice, the diversification of value-added goods (processed rice products) is needed for various customers in the global market. Therefore, the objectives of this study were to process the rice cereal by a twin-screw extruder and to evaluate on physicochemical of extruded rice. Rice cereal processing was conducted with CAR 11 rice as raw material, which had initial moisture content 11.23±0.06% and amylose content 34.74±1.91%, by using a twin-screw extruder and microwave cooking. Three extrusion processing parameters were applied in this study: moisture content of rice flour (18%), screw speed (200-400rpm), and at die temperature (110-140°C). After extrusion, the physicochemical analysis of rice cereal was performed. As the results, moisture content, water activity, pH, color, water absorption index (WAI), and water solubility index (WSI) of rice cereal were 2.32 ± 0.01% to 4.63 ± 0.34%, 0.14 ± 0.01 to 0.21 ± 0.01, 6.57 ± 0.00 to 6.82 ± 0.03, 10.18 ± 0.13 to 18.14 ± 0.11, 5.38 ± 0.10g/g to 7.68 ± 0.19g/g, and 16.35 ± 0.91 % to 41.37 ± 0.38 %, respectively. The findings indicated that an increase in temperature resulted in a decrease in moisture content and color differences, but an increase in WAI and WSI of rice cereal. However, increasing screw speed caused the decrease of WAI and the color brightness L* value. In conclusion, the extrusion processing by a twin-screw extruder had a significant effect on the physicochemical quality of extruded rice cereal. The results in this study are useful information for rice-based cereal further development.*

Keywords: Rice cereal, Extrusion, Twin screw extruder, Physicochemical characteristics

1. INTRODUCTION

Over half of the world's population receives energy from rice, making it one of the major commercial food crops. Globally, it produces around 535 million tons per year which are grown in fifty nations, with China and India producing half of the world's total [1]. Rice is classified into three varieties: Japonica, Javanica, and Indica. Japonica rice cultivars provide a high yield and are disease-resistant. In terms of productivity, usage, and hardiness, Javanica rice cultivars fall between Japonica and Indica kinds. Although fairly hardy, Indica forms yield less than japonica types and are typically planted in the tropics such as Cambodia [1].

Nearly 90% of the cropland in Cambodia is used for rice farming. The majority of the crop is consumed domestically. Nearly half of the production of the agricultural industry is attributed to the rice subsector. With greater government support, the nation's overall rice production rose from about 1 million tons in the mid-1990s to 8.8 million tons in 2013 (wet and dry season harvests combined). The amount of milled rice exported by Cambodia in 2013 was 0.6 million tons [2].
Both rice and milled rice are exported. Very few completed rice products are exported from Cambodia. Only a small number of rice-based products are produced in Cambodia, utilizing a traditional technique. Many traditional Khmer foods and drinks, including rice noodles, rice vermicelli, rice paper, Banh Hoi, Banh Kanh, wine, snacks, and desserts, use rice as a base ingredient. These products are all

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well-known and often used in Cambodia [3]. They are made from the Indica rice varieties [4], such as Raing Chey, CAR, Phkar Romdoul, Chul'sa, and IR66 which is suitable for the production of rice-based products owing to its high amylose content with a range between 22.2% - 40% [5].

Extrusion is an extremely flexible cooking method that combines several unit processes into one method. As a result of shear, which is caused by the action of the screws and the material's particles rubbing against each other, the food material is exposed to compaction, shearing, particle size reduction, phase transition, and molecular breakdown during the extrusion process [6]. All of this occurs rather quickly, usually in less than a minute of extruder residence time.

In fact, most Cambodians eat breakfast made from rice. To adapt to new lifestyle which are simple, time-saving and nutritious, rice cereal could be an option to replace the regular breakfast. The production of rice cereal has not been abundant in Cambodia. Therefore, the aim of this study was to process the rice cereal made from a Cambodian rice variety by the twin screw extrusion processing, and to evaluate the physicochemical of extruded rice cereal after microwave cooking.

2. METHODOLOGY

2.1. Sample collection and preparation

A rice variety, CAR 11, from Siem Reap province was selected for this study. The rice sample was ground into flour by using a fine grinder with 1.66mm sieve. Moisture content and amylose content of the raw rice flour were determined before extrusion processing.

2.2. Extrudate preparation

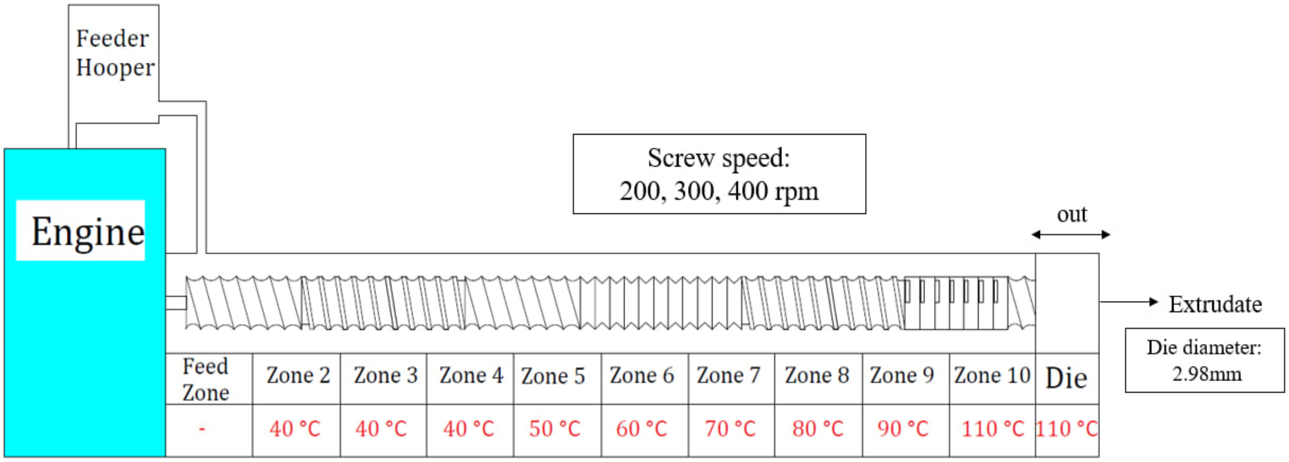
The extrusion study was conducted using a lab-scale co-rotating twin-screw extruder (model TSE 24MC 40:1). The screw diameter and length/diameter ratio of the extruder were 24 mm and 40:1, respectively. The extruder barrel had ten zones. Throughout the trials, the temperatures in the second, third, fourth, fifth, sixth, seventh, eighth, and ninth zones were kept constant at 40, 40, 40, 50, 60, 70, 80, and 90°C, whereas the temperatures in the tenth zone and die zone were changed in accordance with the experimental design (**Figure 1**). The diameter of die opening was 2.98mm. The extruder was equipped with a torque indicator, which showed the torque in proportion to the current drawn by the drive motor. The extruder was calibrated thoroughly with respect to the combination of feeding rate and screw speed to be used. The feeding rate was 60 g/min and the desired moisture content of feed (18%) was adjusted using a water pump. The rice flour sample was poured into the feed hopper at a set feeding rate once the extruder reached the set and stable temperatures. The extrudates were collected at the die end and then dried at 80 ± 0.5°C in a hot air oven for 20 min. After that, the dried extrudates were puffed by the microwave at 1000 w for 20 seconds. The samples were packed in zip bags and stored at room temperature for further analysis.

2.3. Amylose content analysis

The amylose content of rice sample (CAR 11) was analyzed using iodine binding method [8]. Pure potato amylose was used to create the standard curve. First, 40 mg of potato amylose was precisely weighed in a 100 ml volumetric flask. After that, 9 ml of NaOH (1N) and 1 ml of ethanol (95%) were added, and the mixture was heated for 15 minutes in a pot of boiling water. Then, the solution was cooled and filled up to 100ml with distilled water. After diluting the solution, 1 ml, 2 ml, 3 ml, 4 ml, and 5 ml of the solution were added to 5 separate volumetric flasks, along with 0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml, and 1 ml of acetic acid (1N), respectively. So, the concentration of the standard solution is 8mg/ml, 16mg/ml, 24mg/ml, 32mg/ml, and 40mg/ml, respectively. Afterward, 2 ml of iodine solution (0.2%) was added to the 5 flasks, filled up to 100ml with distilled water and stored in a dark box for 20 minutes. Then, the absorbance of all standard solutions was measured at wavelength 620 nm using UV-vis spectrophotometer (Cary 60 UV-Visible, Agilent, USA).

The 100 mg of sample was weight and then 9 ml of NaOH (1N), 1 ml of ethanol (95%) were added in a 100 ml volumetric flask. Then the solution was heated by boiling water for 15 minutes, in order to gelatinized starch. The gelatinized starch was cooled and filled up to 100ml with distilled water. After that, 5 ml of the solution was poured into another 100 ml volumetric flask. Afterward, 1 ml of 1N acetic acid and 2 ml of 0.2% iodine solution were added into the flask and made up to 100 ml with distilled water and the solution was kept in a dark place for 20 minutes and measured in UV-vis spectrophotometer (Cary 60 UV-Visible, Agilent, USA) at wavelength 620 nm. The amylose contents in samples were determined by referring to the standard curve and expressed as percentage.

2.4. Moisture content analysis



Temp. Profiles	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Die
110°C	40	40	40	50	60	70	80	90	110	110
125°C	40	40	40	50	60	70	80	90	125	125
140°C	40	40	40	50	60	70	80	90	140	140

The moisture content of rice flour and extruded samples was determined by following AOAC method (AOAC method (2000)). First, aluminum plates were heated at 103.5 °C in oven for 1 hour, then moved into an airtight desiccator 15 min and weighed. Next, 2 g of samples was weighed in the aluminum plate. After that, the plates with the sample were moved into an oven at 103.5±0.5°C for 3 hours. After drying, the samples in aluminum plates were placed into the desiccator to cool down to room temperature. Finally, the samples in aluminum plates were reweighted. Then the moisture content was calculated by following formula (Eq.1).

$$\text{Moisture content } (\%) = \frac{(W1 - W2\ )}{W1} \times 100 \qquad \text{(Eq.1)}$$

where: W_1= weight of sample before drying (g)
W_2 =weight of sample after drying (g)

2.5. Water activity analysis

The water activity of rice flour and extruded samples was evaluated by using water activity meter (AQUALAB PAWKIT). 3g of grinded rice cereal was weighted into a small plate and was measure by Aqualab device. The water activity was determined in the ambient temperature. The analyze of water activity were done in duplicate.

2.6. pH analysis

A 5g of ground cereal sample was mixed with 45 ml of distilled water in a beaker. It was stirred continuously for 1 minute until homogeneous. The pH of the solution was measured by a pH meter (LAQUA F-72-HORIBA). The pH meter was calibrated using standard pH values of 4, 7 and 10.

2.7. Color measurement

The color of extruded rice sample was measured by a portable colorimeter (Chroma CR400, Konica-Minolta Ltd., Osaka, Japan), according to the CIELAB color space. Angular coordinates were used to express the results (L*, a*, and b*). The samples were done in triplicate. The total color difference was calculated using the below formula (Eq.2). (Eq. 1)

$$\Delta E = \sqrt{(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2} \qquad \text{(Eq.2)}$$

Where ΔE is the total color difference,
ΔL* represents a lightness difference between the sample and standard colors,
Δa* represents the difference in redness or greyness between the sample and standard colors,
Δb* denotes blueness-yellowness differences between the sample and standard colors.

2.8. Water solubility index and water absorption index

Water absorption index (WAI) and water solubility index (WSI) was determined by following the method described in Yousf et al.,2017 [9]. The rice cereal was ground to pass through 30 mesh sieves. 2.5 g of the ground extrudate was suspended in 25 ml of water for 30 minutes at room temperature with steady stirring, and then it was centrifuged at 3,000 g for 15 minutes. A known-weight aluminum dish was used to decant the supernatant, which was then dried at 105 °C in convective air oven until a constant weight was reached. The tube containing the precipitate was also weighed (Eq.3).

WSI is expressed as the weight of dry solids in the supernatant stated as a percentage of the sample's original weight, and WAI is 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 as (Eq.4).

$$WAI = \frac{MR}{MS - MER} \quad \text{(Eq.3)}$$

$$WSI = \frac{MER}{MS} \times 100 \quad \text{(Eq.4)}$$

Where, WAI = water absorption index (g/g); WSI = water solubility index (%)

MR = mass of the centrifuge residue (g)

MS = sample mass (dry basis) (g)

MER = mass of the supernatant evaporation residue (g).

2.9. Data analysis

Analysis of all samples were performed in triplicates. The data obtained were expressed as mean ± standard deviation and subjected to analysis of variance (ANOVA) using statistical software (SPSS version 26.0). The significant differences were determined at $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1. Amylose and moisture content of rice flour

Amylose content plays an important role in evaluating the cooking, consumption, and pasting properties of rice. Amylose content is the second main component of rice starch. Based on amylose content, it can be divided into five categories based on the level of amylose: waxy rice (0–2%), very low (2–12%), low (12–20%), intermediate (20–25%), and high (>25% amylose) [10]. The amylose content of selected flour (CAR 11) was 34.74 ± 1.91% (**Table 1**). These results were similar to those from the previous study, which showed that the amylose contents of Indica rice (IR) starch was 26.14%. Amylose is important in film forming in direct-expanded extruded products. Products high in amylose tend to exhibit a softer bite and lack the crunchiness associated with many direct-expanded snacks.

Moisture content is an important parameter in determining the stability of rice during storage [11]. In this study, the moisture content of rice (CAR 11) was 11.23 ± 0.06% (**Table 1**). Alternatively, the formed pellets can be dried to a shelf-stable moisture in the range of 10%–12%before the final processing step.

Table 1. Moisture and Amylose content of CAR 11 rice

Sample	Moisture content (%)	Amylose content (%)
CAR 11	11.23 ± 0.06	34.74 ±1.91

The data shown were mean ± standard deviation of three replicates.

3.2. Moisture content and water activity of rice cereal

The moisture content of rice-based cereal ranges from 2.32 ± 0.00% to 4.63 ± 0.34%, which was found significant difference $p < 0.05$ (**Figure 2**). Other studies found that the extruded rice cereal has a moisture content that ranges from 2.54% to 10.66% [12]. The highest moisture content was achieved at S300T110 (4.63 ± 0.34 %) when the extrusion temperature of zone 10 was 110 °C, the die temperature was 110 °C, the screw speed was 300 rpm. Similarly, in comparison of S200T125 (4.02± 0.02 %) to all conditions had found significant different $p < 0.05$. However, there were found no significant different ($p > 0.05$) in comparison of S400T140 (3.03 ± 0.05 %) to S200T110 (2.59 ± 0.21 %), S200T140 (2.59 ± 0.30 %), S300T125 (2.61 ± 0.11 %), S300T140 (3.05 ± 0.31 %) and S400T125 (3.26 ± 0.37%), respectively. It means that the moisture content of the extrudates was low at higher extrusion temperatures. This result of moisture evaporating was more enhanced at higher temperatures. The moisture content of the extrudates decreased as the screw speed increased. A high screw speed may increase the evaporation of moisture by heating the screw through friction. One study which research on optimization the extrusion conditions for the production of expanded intermediate wheatgrass products reported that screw speed and extrusion temperature had significant negative effects on the moisture content of the extrudates, however, their interaction had a significant positive effect [13].

A water activity determination was performed to estimate accessible water in foods. Water activity will indicate the growth of undesirable microorganisms, identify potential food hazards, regulate package specifications, and have an impact on food packaging standards [14]. The degree of water binding, dissociation, solubility of the solutes in the water, or matrix state fluctuations all contributed to its dependence on water. Temperature on the barrels alter water activity [15]. **Figure 3**. indicates that the resulted water activity of rice-based cereals ranged from 0.14 ± 0.01 to 0.21 ± 0.01, which was has significant difference with a $P<0.05$. According to other study

[12], the water activity of the ready-to-eat cereals ranged from 0.11 to 0.50.

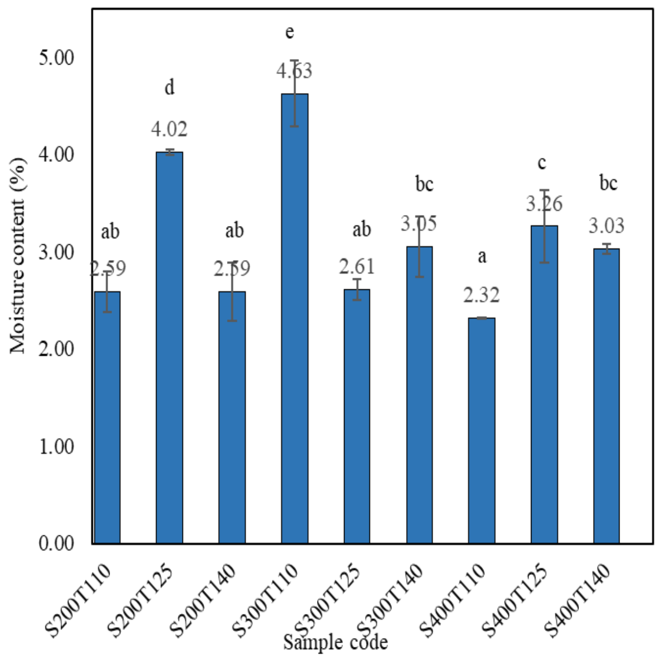


Figure 1. Moisture content of rice cereal ; *S200T110: Screw speed 200 rpm, with die temperature 110°C; S200T125: Screw speed 200 rpm, with die temperature 125°C; S200T140: Screw speed 200 rpm, with die temperature 140°C; S300T110: Screw speed 300 rpm, with die temperature 110°C; S300T125: Screw speed 300 rpm, with die temperature 125°C; S300T140: Screw speed 300 rpm, with die temperature 140°C; S400T110: Screw speed 400 rpm, with die temperature 110°C; S400T125: Screw speed 400 rpm, with die temperature 125°C; S400T140: Screw speed 400 rpm, with die temperature 140°C*

Among 9 conditions of extruded rice-based cereal (**Figure 3**.), the highest of water activity was in S200T110 (0.21 ± 0.01). The reason that it has high water activity among the extrudate is probably due to its low temperature in the die zone of 110 ℃ and low screw speed of 200 rpm. On the other hand, the lowest amount of water activity were S300T140 (0.14 ± 0.01) and S400T140 (0.14±0.01) due to the high temperature in its die zone and also the high screw speed of 300 and 400 rpm since water activity is temperature dependent [15]. In comparison of S200T125 (0.17 ± 0.01) to S300T125 (0.18 ± 0.01), S400T125 (0.16 ± 0.01) to S200T140 (0.16 ± 0.01) and S400T110 (0.16 ± 0.01), and S300T140 (0.14 ± 0.00) to S400T140 (0.14 ± 0.01), there were no significant difference among these samples (P > 0.05).

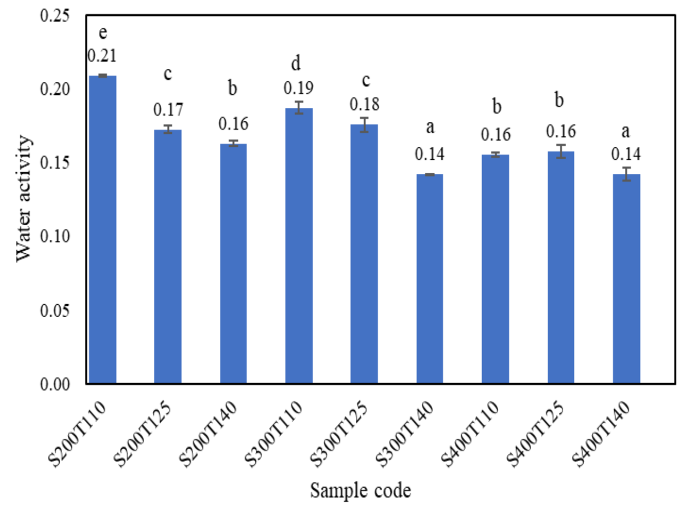


Figure 3. Water activity of rice cereal; *S200T110: Screw speed 200 rpm, with die temperature 110°C; S200T125: Screw speed 200 rpm, with die temperature 125°C; S200T140: Screw speed 200 rpm, with die temperature 140°C; S300T110: Screw speed 300 rpm, with die temperature 110°C; S300T125: Screw speed 300 rpm, with die temperature 125°C; S300T140: Screw speed 300 rpm, with die temperature 140°C; S400T110: Screw speed 400 rpm, with die temperature 110°C; S400T125: Screw speed 400 rpm, with die temperature 125°C; S400T140: Screw speed 400 rpm, with die temperature 140°C*

3.3. pH of rice cereal

The pH has the power to influence chemical behavior, microbial activity, biological reactions, and nutritional availability [16]. Because of this, controlling or monitoring the pH of food products is important for a wide variety of applications. **Figure 4.** shows that the pH value of the extruded rice-based cereal ranged from 6.57 ± 0.00 to 6.82 ± 0.03 which were significant difference with $P < 0.05$. Normally, the pH value of rice is within the range of 6 to 7 pH, though it can vary with different types. Due to approximate pH of Krispies rice is around 6.00-6.70 [17]. Depending on the brand and the specific components used in its manufacture, the pH of instant rice-based cereal may differ. One of the key factors in the extruded rice cereal is the type of rice utilized. Due to the different varieties with different pH values, the pH of the final product might change depending on the type that was used. No significant different (p > 0.05) were found when comparing the pH of rice cereal at S200T110 (6.79 ± 0.01) to S200T140 (6.82 ± 0.03), S300T125 (6.79 ± 0.01), and S400T110 (6.78 ± 0.01). Similarly, in comparison of S200T125 (6.58 ± 0.01) to S400T125 (6.57 ± 0.00), and S300T110 (6.64 ± 0.01) to S300T140 (6.65 ± 0.00) and S400T140 (6.62 ± 0.01) were found no significant different (p > 0.05).

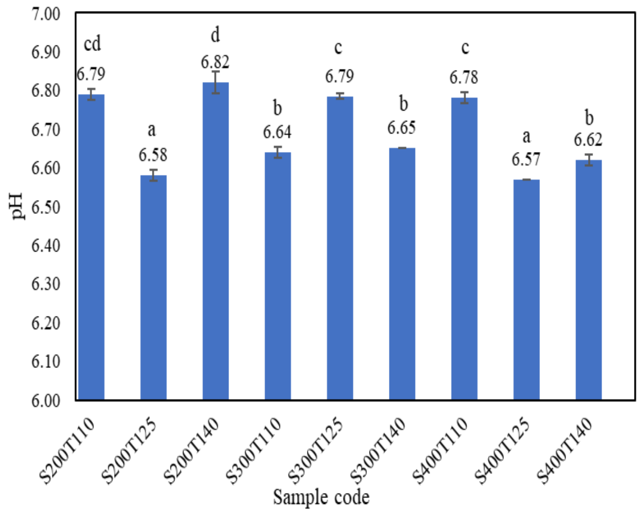


Figure 4. pH of rice cereal; *S200T110: Screw speed 200 rpm, with die temperature 110°C; S200T125: Screw speed 200 rpm, with die temperature 125°C; S200T140: Screw speed 200 rpm, with die temperature 140°C; S300T110: Screw speed 300 rpm, with die temperature 110°C; S300T125: Screw speed 300 rpm, with die temperature 125°C; S300T140: Screw speed 300 rpm, with die temperature 140°C; S400T110: Screw speed 400 rpm, with die temperature 110°C; S400T125: Screw speed 400 rpm, with die temperature 125°C; S400T140: Screw speed 400 rpm, with die temperature 140°C*

3.4. Color measurement of rice cereal

Color is an essential indicator of product quality that is directly related to consumer approval of food products and is an important characteristic to note for extruded products. The colorimeter results in the three-color component values L* (black-white component, brightness), a* (green to red component), and b* (yellow to blue component). The color changes of the extruded rice cereal compared to its uncooked rice flour. The mean *L**, *a**, and *b**values prior to extrusion cooking were 91.07, -0.31, and 5.18, respectively for the rice flour. The *L** of the extruded sample was expected to be lower than the rice flour before cooking, while *a**, *b** were expected to be higher than the rice flour before cooking due to the darkened color caused by browning. Therefore, lower values of *L** and higher values of *a**, *b** correspond to darker color of extrudates after cooking [18].

The difference in color change between extrudates can be attributed to the different extrusion conditions. It was found that screw speed, and barrel temperature, had significant different on the changes of extrudate color ($P < 0.05$). Severe extrusion conditions, which correspond to low values of *L** and high values of *a**, and *b**, are usually caused by low moisture content, high screw speed, high barrel temperature, and screw configuration with more reverse elements [18].

As can be seen in **Table 2.** the result indicated that the color of L*, a*, b* and ΔE values of extruded rice cereal ranged from 73.44 ± 0.13 to 81.23 ± 0.12, -1.04 ± 0.03 to -0.62 ± 0.06, 7.00 ± 0.04 to 10.28 ± 0.19, and 10.18 ± 0.13 to 18.14 ± 0.11, respectively which were significant difference ($P<0.05$). There are several processes that happen during extrusion that affect the extrudate's color. The most common process is browning without enzymes. The most significant characteristic of the non-enzymatic browning reaction is the creation of the colored compound, which has an impact on the look of the extruded product [19]. The product's lightness was significantly impacted by the high-temperature extrusion [20].

Table 2. Color of rice cereal

Sample code	L*	a*	b*	ΔE
S200T110	74.14 ± 1.07^{a}	-0.63 ± 0.03^{e}	7.12 ± 0.27^{a}	17.05 ± 1.04^{f}
S200T125	79.84 ± 0.25^{d}	-0.77 ± 0.03^{c}	7.00 ± 0.04^{a}	11.39 ± 0.25^{b}
S200T140	78.51 ± 0.28^{c}	-0.62 ± 0.06^{e}	8.88 ± 0.09^{c}	13.10 ± 0.29^{d}
S300T110	81.23 ± 0.12^{e}	-0.74 ± 0.05^{d}	7.72 ± 0.08^{b}	10.18 ± 0.13^{a}
S300T125	80.81 ± 0.44^{e}	-0.74 ± 0.03^{d}	9.34 ± 0.13^{d}	11.08 ± 0.43^{b}
S300T140	76.38 ± 0.30^{b}	-1.04 ± 0.03^{a}	8.71 ± 0.04^{c}	15.13 ± 0.29^{e}
S400T110	73.44 ± 0.13^{a}	-0.81 ± 0.01^{c}	9.43 ± 0.05^{d}	18.14 ± 0.11^{g}
S400T125	79.48 ± 0.21^{d}	-0.93 ± 0.03^{b}	9.23 ± 0.09^{d}	12.30 ± 0.18^{c}
S400T140	76.71 ± 0.33^{b}	-0.95 ± 0.03^{b}	10.28 ± 0.19^{e}	15.26 ± 0.24^{e}

The data shown were mean ± standard deviation of three replicates; S200T110: Screw speed 200 rpm, with die temperature 110°C; S200T125: Screw speed 200 rpm, with die temperature 125°C; S200T140: Screw speed 200 rpm, with die temperature 140°C; S300T110: Screw speed 300 rpm, with die temperature 110°C; S300T125: Screw speed 300 rpm, with die temperature 125°C; S300T140: Screw speed 300 rpm, with die temperature 140°C; S400T110: Screw speed 400 rpm, with die temperature 110°C; S400T125: Screw speed 400 rpm, with die *temperature 125°C; S400T140: Screw speed 400 rpm, with die temperature 140°C*

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

Water absorption and water solubility index are the key functional characteristics of extruded starches when they are dispersed in an excess of water.

The WAI of the extruded rice cereal was ranged from 5.38 ± 0.10 g/g to 7.68 ± 0.19 g/g (**Figure 5)**, which were significant difference($P<0.05$). The WAI of extruded snacks, according to [21], ranged from 3.65 g/g to 4.78 g/g, which was lower than the WAI discovered in our study. The WAI decreased as the screw speed increased [19]. The highest WAI of extruded rice cereal was recorded in S200T140 which is use screw speed in 200 rpm with die temperature 140 °C. The lowest WAI of extruded rice cereal was in S300T110 (5.38 ± 0.11g/g) which was found significant different ($p < 0.05$). Others study were reported that a decrease in WAI cause an increase in screw speed [20;21]. Moreover, other finding reported that the increasing of barrel temperature, it also causes the increase of WAI [9]. In addition, there were significant different found in S200T140 (7.68 ± 0.19g/g) compared to S200T110 (6.87 ± 0.67g/g), S300T110 (5.38 ± 0.11g/g), S300T140 (6.79 ± 0.37g/g), S400T125 (6.94 ± 0.10g/g) and S400T140 (6.82 ± 0.38g/g), respectively.

The degree of breakdown of macromolecules during extrusion, such as fiber and starch granules, is usually measured using the WSI. It is frequently used as an indicator for the amount of soluble compounds that have been released from the material's starch component during extrusion. Having a high WSI or being very soluble in the liquid medium is undesirable since breakfast cereals are frequently served with liquid milk or water [13]. As can be seen in the **Figure 6**. the resulted shown that the WSI was ranged from 16.35 ± 0.91% to 41.37 ± 0.38%, which were significance difference ($P<0.05$). According to the study of Boakye., 2022, said that the WSI of extruded snack were ranged from 15.91% to 38.98% [13], which were lower than our study. The highest WSI was recorded in S400T140 (41.37 ± 0.38%), while the lowest WSI was recorded in S200T140 (16.35 ± 0.91%) were found significant different ($p < 0.05$). Additionally, starch degrades into smaller molecular weight fractions with increased solubility at higher temperatures, which increases the WSI. In contrast, there were no significant different found in comparing of S300T125 (30.55 ± 4.56%) to S200T125 (28.85 ± 0.38%), S300T110 (34.89 ± 0.09%), S300T140 (35.69 ± 0.26%), S400T110 (28.28 ± 4.37%), and S400T125 (35.75 ± 0.17%).

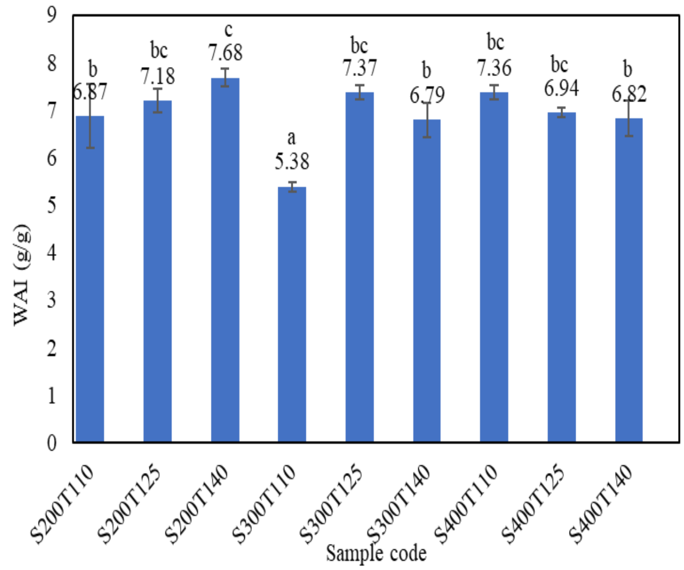


Figure 5. Water absorption index of rice cereal; *S200T110: Screw speed 200 rpm, with die temperature 110°C; S200T125: Screw speed 200 rpm, with die temperature 125°C; S200T140: Screw speed 200 rpm, with die temperature 140°C; S300T110: Screw speed 300 rpm, with die temperature 110°C; S300T125: Screw speed 300 rpm, with die temperature 125°C; S300T140: Screw speed 300 rpm, with die temperature 140°C; S400T110: Screw speed 400 rpm, with die temperature 110°C; S400T125: Screw speed 400 rpm, with die temperature 125°C; S400T140: Screw speed 400 rpm, with die temperature 140°C*

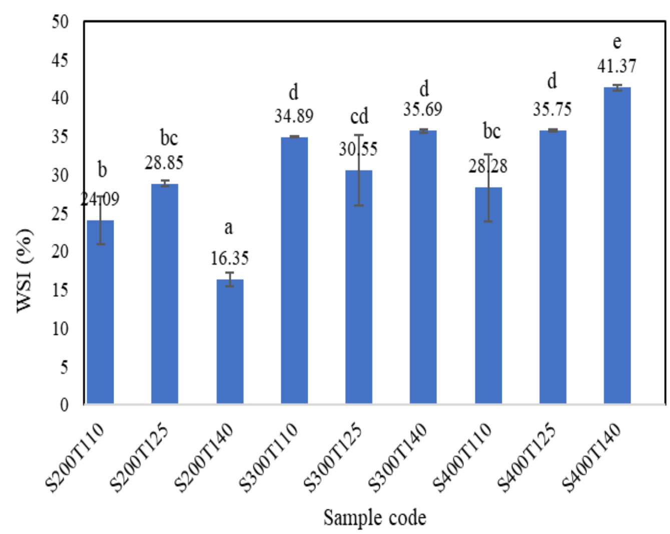


Figure 6. Water solubility index of rice cereal; *S200T110: Screw speed 200 rpm, with die temperature 110°C; S200T125: Screw speed 200 rpm, with die temperature 125°C; S200T140: Screw speed 200 rpm, with die temperature 140°C; S300T110: Screw speed 300 rpm, with die temperature 110°C; S300T125: Screw speed 300 rpm, with die temperature 125°C; S300T140: Screw speed 300 rpm, with die temperature 140°C; S400T110: Screw speed 400 rpm, with die temperature 110°C; S400T125: Screw speed 400 rpm, with die temperature 125°C; S400T140: Screw speed 400 rpm, with die temperature 140°C*

4. CONCLUSION

This study was conducted on the rice cereal with extrusion processing and quality control on the physicochemical parameters at 18% feed moisture, zone 10 and die temperature ranging from 110°C to 140°C, screw speeds ranging from 200 rpm to 400 rpm. Based on the results obtained, the screw speed and temperature had the effect on the physicochemical properties of rice cereal. The increasing of temperature caused decreasing of moisture content, water activity and total color difference. The higher screw speed and barrel temperature decreased the water absorption index, while the higher temperature barrel increased the water solubility index. For further study are required on starch of raw rice flour, nutrition value and expansion ratio of rice cereal by various extrusion parameters.

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AUTHOR CONTRIBUTIONS

Rathana Sovann designed, conducted the experiments, analyzed date, and drafted the manuscript. Hassany Ly assisted the extrusion experiments and physicochemical analyze. Pichmony Ek developed the initial design, idea, and edited the manuscript. Sokuntheary Theng and Hengsim Phoung helped check on the grammar in the manuscript. Hasika Mith provided oversight for whole project.

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