Product development of dried noodle from wheat flour and riceberry rice flour by extrusion

P Chokchaithanawiwat¹, V Rungsardthong¹, B Thumthanaruk¹, C Puttanlek², D Uttapap³, S Boonraksa⁴ and J Wonngsa⁵, ⁶

¹Department of Agro-Industrial, Food and Environmental Technology, Faculty of Applied Science, Food and Agro-Industry Research Center, King Mongkut’s University of Technology North Bangkok, Bangkok, Thailand
²Department of Biotechnology, Faculty of Engineering and Industrial Technology, Silapakorn University, Nakhon Pathom, Thailand
³Division of Biochemical Technology, School of Bioresources and Technology, King Mongkut’s University of Technology Thonburi, Bangkok, Thailand
⁴Bioplus Innovate Company Limited, Bang Phli, Samut Prakan, Thailand
⁵Department of Agricultural Engineering for Industry, Faculty of Industrial Technology and Management, King Mongkut’s University of Technology North Bangkok Prachinburi Campus, Prachinburi, Thailand

E-mail: jittimon.w@fitm.kmutnb.ac.th

Abstract. Riceberry rice (Oryza sativa L.), a cross-breed of Khao Hom Nin, a local non-glutinous purple rice and Khao Hom Mali 105 contains antioxidants and other significant bioactive constituents in its bran fraction. This research aimed to produce noodle from riceberry rice and wheat flour by direct extrusion. In this study, the effects of barrel temperature, riceberry flour ratio, and food additives (sodium carbonate, guar gum and xanthan gum) on appearance and cooking qualities of extruded riceberry noodles were examined. Riceberry flour at 5%, 10%, 15% and 20% (by weight) was mixed with wheat flour via a single screw extruder with 0.8 mm diameter die, 30% feed moisture content (wet weight basis), screw speed of 40 rpm and the third barrel temperatures at 90:100:100 °C, respectively. Experiments were conducted to find appropriate food additives by using mixture design of 3 components (sodium carbonate, guar gum and xanthan gum) and barrel temperature controlled between 90-110 °C. The result showed that riceberry flour substitution could be used up to 15% with acceptable properties. The addition of guar gum and xanthan gum at 0.8% and 2.0%, respectively, could be used leading to rice noodle with cooking time 3.0 min and cooking loss 3.63%, comparable to the product made by conventional method (as the control formula).

1. Introduction
Riceberry, dark purple grain; (Oryza sativa L.), is a cross-bred strain developed from Hom Nin Rice variety with high antioxidant, and the well-known fragrant rice Khao Dawk Mali 105 developed by the Rice Research Center, Kasetsart University (Kamphaeng Saen Campus), Nakhon Pathom, Thailand [1]. Riceberry rice is a aromatic new rice variety that has black/purple in color, light and fluffy in texture when cooked. In addition, it is rich in antioxidants which support immunity, has anti-ageing properties and has high fiber and bran oil to aid digestion [2]. Nowadays, people are getting more and more
interested in the properties of antioxidants that promote good health. Naturally extracted antioxidants have become popular as they can prevent cell damage from free radical reactions and reduce the risk of various chronic diseases like cardiovascular disease, atherosclerosis, cancer and diabetes [3].

Asian people consume noodles as a staple food since ancient time. It is convenient, easy to cook and delicious product. A noodle strand was made from rice flour that was kneaded with water and salt which resulted in dough that can be pressed to produce a thin sheet before being streamed and then sliced into thin strands [4].

The production of noodles with traditional methods has many complex long production processes. Therefore, the risk of microbial contamination exists with high waste and large production space requirement. Extrusion has been used to produce noodle strands due to its multi-function ability including, in successive order, mixing, kneading, cooking, and forming the noodles. The process can be quickly executed by a single machine that runs continuously [5]. Moreover, extrusion offers significant economic advantages accruing from decreased energy and less floor space requirement and product quality can be improved through the better process uniformity and control [5]. Presently, food additives like emulsifiers (glycerol monostearate, soya lecithin and sodium stearoyl lactylate), gums (xanthan gum, guar gum, acacia gum and carrageenan) and dough strengthener (sodium carbonate) are used to improve the cooking properties and texture of the extruded rice-flour-based products [6-7]. Therefore, the objective of this study was to develop noodle with substitution of riceberry flour to wheat flour by using direct extrusion. In the present study ratio of riceberry rice flour, extrusion temperature and use of food additives on the noodle properties were investigated.

2. Material and methods

2.1. Materials
Riceberry rice (Oryza sativa L.) was obtained from Bioplus Innovate Co., Ltd (Thailand), and sodium carbonate, guar gum and xanthan gum were supplied from M Good Ingredient Co., Ltd (Thailand). Wheat flour, Kite brand was purchased from MC food Co., Ltd., Thailand.

2.2. Chemical analysis
The chemical compositions of riceberry flour and wheat flour were analyzed according to AOAC method [8].

2.3. Preparation of noodles by direct extrusion
The preparation of flour blend was performed by adding water at 30%wb to wheat flour (85%) and riceberry flour (15%). The mixture was mixed slowly at low speed (level 2) for 15-20 min in a mixer (Kenwood) before feeding into a single screw extruder (Barbender -19/20 Barrel Bore (D) 19.1 mm, Barrel Length (L) 20D, screw compression ratio 4:1) with the die diameter at 0.8 mm. Screw speed was operated at 40 rpm and barrel temperatures were maintained at 90 °C (first zone), 100 °C (second zone) while the effect of the third barrel temperature on the properties of extruded noodle was investigated at 90, 100 and 110° C.

2.4. Riceberry flour ratio and use of food additives
Riceberry flour, instead of wheat flour, has been used to produce noodles by extrusion process at 5, 10, 15 and 20% (by weight). The extruded samples were placed in the dryer with 12% moisture content for 25°C 24 h at room temperature. The noodle quality was improved by using food additives such as sodium carbonate, guar gum and xanthan gum by the mixture design experiment.

Wheat and riceberry noodles prepared by traditional method served as control. Wheat flour was mixed with riceberry flour at 20% (by weight) by using a Kenwood mixer and kneaded in to a dough, and incubated at room temperature for 30 min. The sheet was cut into 2.0 mm width by using a noodle slitter and steamed. To achieve dried product, the streamed noodles was left in a hot air oven for 4 hours at the drying temperature of 50°C.
2.5. Cooking qualities
Cooking qualities of the cooked noodles including cooking time and cooking loss were evaluated following Wandee et al. [9]. Cooking time of noodle was evaluated by observing the time of disappearance of the core of the noodle strand during boiling (every 30 s) by squeezing the noodles strand between two glass slides. Quantification of cooking loss was achieved by measuring residue left in water that was used in the cooking process. The experiment involved boiling of 10 g noodle in 300 ml of distilled water in a 500 ml beaker. Consequently, the cooking water was transferred into an aluminium container and placed in an oven at 105 °C. After the water was completely evaporated, the remaining material was weighted and calculated against the original quantity of the material. Mean value of the experiments was assessed to evaluate the cooking loss.

2.6. Noodle color analysis
Hunter Lab, Color Quest 450/0, (Australia) with a D65 illuminant using the CIE L*a*b* system was used to determine the colour of dried noodle strands. The obtained values signified the colours which were classified as lightness, redness and yellowness, respectively. The assessments were conducted 3 times for each sample.

2.7. Statistical analysis
Statistical Package for the Social Sciences version 22.0 software (SPSS Inc., Chicago, IL, USA) was used to evaluate statistical information. The results revealed mean average values of the triplicate experiments with ± the standard deviation (S.D.). However, the results did not apply to the textural assessment. Variance was determined by one-way analysis where differences between the mean values were assessed by Duncan’s multiple range tests at a significant level of p < 0.05.

3. Result and discussions
3.1. Proximate compositions
Chemical compositions of riceberry flour and wheat flour are shown in Table 1. It was found that ash and lipid content of riceberry flour were higher than that of wheat flour while protein of riceberry flour was higher than that of wheat flour. [10] reported that protein, lipid, crude fiber and ash contents of riceberry flour were 10.94, 0.91, 2.73 and 1.13 g/100 g, respectively while Fari et al. (2011) [11] and Han et al. (2011) [12] found 6.84-11.18% of protein content in different variety of rice. On the other hand, wheat was found to have higher protein content at 11.65-14.93% [13-14]. Quantity of protein in rice may differ, depending on the variety of rice [12]. As pasting properties formed a strong network of protein and starch molecules, flour with higher protein content exhibits more binding sites for the starch which consequently resulted in higher water holding capacity [15-17].

| Chemical compositions (%)               | Riceberry flour | Wheat flour |
|----------------------------------------|-----------------|-------------|
| Moisture content (ns)                  | 9.67±0.39       | 9.24±3.03   |
| Ash                                    | 1.36±0.02       | 0.50±0.01   |
| Protein                                | 8.33±0.04       | 10.92±0.05  |
| Lipid                                  | 3.79±0.03       | 1.81±0.02   |
| Carbohydrate (ns)                      | 76.85±0.04      | 77.53±0.03  |

Values are mean ± SD of triplicate samples (n=3)
Different superscript letters in the same column indicate significant difference (P≤0.05)
ns = no significant difference (P < 0.05).
3.2. Effect of third barrel zone temperature
In this study, the use of third barrel zone temperature between 90-100°C significantly affected the characteristic of the extruded noodles as shown in Table 2. The surface of noodle strands extruded at 90°C gave wave-like noodle strands, while the temperature of 110°C, the noodle strand's surface was slightly inflated and porous due to the high temperature. However, noodles from all third zone temperature yielded the products with the same cooking time, 4.00 min which might come from same level of gelatinization of the flour mix. Consequently, the barrel temperature of zone 1: 2: 3 was controlled at 90, 100 and 110°C, respectively for following experiment.

Table 2. Effects of third zone temperature on cooking time and appearance of extruded noodle.

| Barrel Temperature (°C) | Appearance | Cooking Time (min) |
|-------------------------|------------|--------------------|
| Zone 1 90 | Zone 2 100 | Zone 3 90          | 4.00±0.01          |
| Zone 1 90 | Zone 2 100 | Zone 3 110         | 4.00±0.01          |

Values are mean ± SD of triplicate samples (n=3).

3.3. Riceberry flour ratio
Appearance of dried noodles and cooking time of cooked noodles from the extrusion of wheat flour with riceberry flour substitution at 5, 10, 15 and 20% (by weight) are shown in Table 3. Color appearance is one of the characters that influence consumer’s preferences. Color, L*, a*, b* of riceberry-made noodles are displayed in Table 3. Riceberry noodle produced by traditional method was used as the control and be compared with the riceberry flour to wheat flour at 5, 10, 15 and 20% (by weight). L* and b* value of the noodles were reduced while a* value increased with the increase of riceberry flour. Higher content of riceberry resulted in more reddish color due to anthocyanin pigment in the riceberry flour [18]. Considering the appearance and color acceptance, the substitution of riceberry flour at 15% (by weight) was selected for further study.

Cooking time of noodles made from wheat flour had longer cooking time than noodles that use partial rice flour instead of wheat flour. The differences in cooking quality were attributed primarily to the gluten content. Gluten fraction dilution was caused by higher riceberry flour content, thus, required
lower heat for the cooking process. As a result, dough properties and the cooking quality were affected by higher riceberry flour content [19].

Table 3. Color characteristics of dried noodles from riceberry rice.

| Sample      | L*          | a*          | b*          | Appearance |
|-------------|-------------|-------------|-------------|------------|
| 5% RF       | 25.74±0.15^b| 1.89±0.01^d| 7.55±0.03^b| ![Image](5) |
| 10% RF      | 21.60±0.09^c| 2.78±0.02^b| 4.17±0.01^c| ![Image](5) |
| 15% RF      | 17.27±0.08^d| 2.95±0.02^a| 1.90±0.05^d| ![Image](5) |
| 20% RF      | 16.38±0.08^a| 2.16±0.13^c| 0.51±0.16^a| ![Image](5) |
| 20% RF (control) | 30.87±0.16^a| 2.74±0.11^b| 9.47±0.20^a| ![Image](5) |

Values are mean ± SD of triplicate samples (n=3)
Different superscript letters in the same column indicate significant difference (P≤0.05)

3.4. Use of food additives on noodle properties
The effects of food additive (sodium carbonate, guar gum and xanthan gum) on the cooking time and cooking loss of extruded noodles explored by mixture design are shown in Table 4. It was found that the noodle with riceberry flour at each formula gave color and appearance slightly different due to different amounts of food additives used in the experiments. Cooking times of noodle ranged from 3.00 to 4.00 min.

Cooking loss is the amount of dry matter in the cooking water at each noodle. An increase in the cooking loss with noodles containing food additives in formula 1, 5-9 (Table 5) may be due to interaction of the food additives at a certain amount, resulted to the property starch gel network and more solid leaching out from the noodles into the cooking water. Formular 2 exhibited lowest cooking time and
cooking loss and had better texture properties than other the formula, determined by preliminary sensory testing. Kaur et al. (2015) [20] reported that the noodles prepared with guar gum and xanthan gum showed significantly lower cooking loss than that prepared without the guar gum and xanthan gum.

**Table 4.** Appearance and cooking time of extruded noodles prepared from wheat flour substituted with riceberry flour at different percentage.

| Samples  | Appearance | Cooking Time (min) |
|----------|------------|--------------------|
| 0% RF    | ![Image](image1.png) | 4.50±0.01          |
| 5% RF    | ![Image](image2.png) | 4.00±0.01          |
| 10% RF   | ![Image](image3.png) | 4.00±0.01          |
| 15% RF   | ![Image](image4.png) | 4.00±0.01          |
| 20% RF   | ![Image](image5.png) | 4.00±0.01          |
| 20% RF   | ![Image](image6.png) | 3.50±0.01          |

Values are mean ± SD of samples (n=3), RF = riceberry flour
Table 5. Cooking time, cooking loss and cooking yield of noodles from wheat flour and riceberry flour with various food additives.

| Formula | Na$_2$CO$_3$ | Guar gum | Xanthan gum | Cooking time (min) | Cooking loss (%) |
|---------|--------------|----------|-------------|-------------------|-----------------|
| 1       | -            | 1        | -           | 3.50±0.01         | 45.27±0.06c     |
| 2       | -            | 0.8      | 2           | 3.00±0.00         | 3.63±0.02f      |
| 3       | 0.3          | 0.7      | -           | 4.00±0.00         | 6.40±0.03ef     |
| 4       | 0.3          | 0.5      | 2           | 3.50±0.01         | 6.72±0.08e      |
| 5       | 0.15         | 0.75     | 1           | 4.00±0.00         | 76.08±0.01b     |
| 6       | 0.075        | 0.875    | 0.5         | 3.50±0.01         | 74.82±0.03b     |
| 7       | 0.075        | 0.775    | 1.5         | 3.00±0.00         | 80.35±0.01a     |
| 8       | 0.225        | 0.725    | 0.5         | 4.00±0.00         | 27.79±0.03d     |
| 9       | 0.225        | 0.625    | 1.5         | 3.50±0.01         | 26.77±0.07d     |

Values are mean ± SD of triplicate samples (n=3) Different superscript letters in a column indicate significant difference. (P < 0.05)

4. Conclusion
This research explored the possibility of using up to 20% of riceberry flour to produce noodles. Extrusion process at barrel temperatures of zone 1: zone 2: zone 3 at 90:100:100°C was used in the process. According to the results, riceberry flour at 15% (by weight basis) produced acceptable color and cooking quality compared to the product from traditional method. Guar gum and xanthan gum at 0.8% and 2.0% respectively were additives used for rice noodles that resulted in the cooking time of 3.0 min and the cooking loss of 3.63%.

Acknowledgment
This research was supported by Office of the Higher Education Commission and Bioplus Innovate Co., Ltd, under the Talent Mobility Program.

References
[1] Rice Science Center of Kasetsart University 2016 Riceberry rice Retrieved from http://dna.kps.ku.ac.th/index.php/articles-ricerse-rgdu-knowledge/29-2015-03-27-02-0415/53-riceberry.
[2] Leardkamolkarn V, Thongthep W, Suttiarporn P, Kongkachuichai R, Wongpornchai S and Wanavijitr A 2011 Chemopreventive properties of the bran extracted from a newly developed Thai rice: The Riceberry. Food Chem 125 978-985.
[3] Pannangrong W, Wattanathorn J, Muchimapura S, Tiamkao S and Tong-Un T 2011 Purple riceberry is neuroprotective and enhances cognition in a rat model of alzheimer's disease. J. Med. Food 14(7) 688-694.
[4] Ahmed I, Qazi I M, Li Z and Ullah J 2016 Rice noodles: Materials, processing and quality evaluation. Proceedings of the Pakistan Academy of Sciences: B. Life and Environmental Sciences 53(3) 215-238.
[5] Miller R C 1988 Continuous cooking of breakfast cereal. Cereal Foods World 33 284-291.
[6] Wongsa J, Uttapap D, Lamsal B P, Puttanlek C and Rungsardthong V 2017 Effect of extrusion conditions, monoglyceride and gum arabic addition on physical and cooking properties of extruded instant rice. *KMUTNB Int J. Appl Sci Technol* 10(1) 23-30.

[7] Wang J P, An H Z, Jin Z Y, Xie Z J, Zhuang H N and Kim J M 2011 Emulsifiers and thickeners on extrusion-cooked instant rice product. *J. Food Sci Technol* 50(4) 655-666.

[8] AOAC 2005 Official Method of Analysis, Association of Official Agricultural Chemist. 12th Ed. Washington, D.C., USA.

[9] Wandee Y, Uttapap D, Puncha-arnon S, Puttanlek C, Rungsardthong V and Wetprasit N 2015 Quality assessment of noodles made from blends of rice flour and canna starch. *Food Chem* 179 85-93.

[10] Jamal S, Qazi I M and Ahmed I 2016 Comparative studies on flour proximate compositions and functional properties of selected Pakistani rice varieties. *Pakistan Acad Sci* 53(1) 47-56.

[11] Fari M J M, Rajapaksa D and Ranaweera K K D S 2011 Quality characteristics of noodles made from selected varieties of Sri Lankan rice with different physicochemical characteristics. *J. Natl Sci Found Sri* 39 53-60.

[12] Han H M, Cho J H and Koh B K 2011 Processing properties of Korean rice varieties in relation to rice noodle quality. *Food Sci Biotechnol* 20 1277-1282.

[13] Ngozi A A 2014 Effect of whole wheat flour on the quality of wheat-baked bread. *J. Glo. Fd Sci. Technolo. 2*(3) 127-135.

[14] Han L, Zhou Y, Tatsumi E, Shen Q, Cheng Y and Li L 2013 Thermo-mechanical properties of dough and quality of noodles made from wheat flour supplemented with different grades of tartary buckwheat flour. *Food Bioprocess Tech* 6 1953-1962.

[15] Rosniyana A and Hazila K K 2013 Nutritional properties and organoleptic acceptability of traditional cakes made from mr 220 rice flour. *J. Trop Agric Fd Sci* 41(1) 41-52.

[16] Chung H J, Cho A and Lim S T 2012 Effect of heat-moisture treatment for utilization of germinated brown rice in wheat noodle. *J. Food Sci Technol* 47 342-347.

[17] Martinez O M, Ayerdi S S, Acevedo E A, Goñiand I, Pérez L A B 2009 Un-ripe banana flour as an ingredient to increase the undigestible carbohydrates of pasta. *Food Chem* 113(1) 121-126.

[18] Yodmanee S, Karrila T T and Pakdeechanuan P 2011 Chemical and antioxidant properties of pigmented rice grown in southern Thailand. *Int. Food Res J* 18(3) 901-906.

[19] Li P H, Huang C C, Yang M Y and Wang C C R 2012 Textural and sensory properties of salted noodles containing purple yam flour. *Food Res Int.* 47 223-238.

[20] Kaur A, Shevkani K, Singh N, Sharma P and Kaur S 2015 Effect of guar gum and xanthan gum on pasting and noodle-making properties of potato, corn and mung bean starches. *J. Food Sci Technol* 52(12) 8113-8121.