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Original Research Article

Addition of dietary fiber for enriched nutrition of gluten-free Macaroni

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ABSTRACT

Pasta is one of the stable food in Western countries. It is growing in popularity worldwide. Pasta consumption provides daily energy due to the presence of carbohydrate, protein and fat, while lacking an important nutrient like dietary fiber. Therefore, the objective of this study was to investigate the effect of dietary fiber addition to the gluten-free pasta. Cooking quality, textural properties, proximate analyses and sensory evaluation were determined. Rice-flour based macaroni mixed with tapioca starch was enriched with different sources of dietary fiber (10% and 20% wheat fiber, 10% and 20% corn meal and 1% and 1.5% cellulose fiber). Results showed that the incorporation of cellulose fiber provided the highest cooking time (9.00±0.87 min), the highest water absorption (119.03±5.18%), the highest firmness (4.23±0.38 N) and the acceptable cooking loss (4.26±0.15%) among the other formulations. Cooking loss increased when higher amount of the fiber sources was added. All gluten-free macaroni had cooking loss (2.73±0.31 to 4.89±0.29%) and water absorption (94.99±1.13 to 119.03±5.18%). Corn meal addition appeared to provide desirable color with high value on yellowness (b*) of 20.35±0.10. Increasing work of shearing was observed with the higher fiber content being added. The highest work of shearing was from 1.5% cellulose fiber macaroni (95.2±8.29 g.cm), whereas the lowest was from 10% wheat fiber (55.01±4.23 g.cm). Liking scores from sensory evaluation of gluten-free macaroni showed that significant differences were observed from all formulations on appearances, color, aroma of rice and overall liking ($p \leq 0.05$). Once served with pasta sauce, liking scores on flavor of rice, overall taste and overall liking did not have significant differences among formulations ($p > 0.05$). Addition of wheat fiber, corn meal or cellulose fiber resulted in an increase of crude fiber content (up to 6.99±0.19%) in gluten-free macaroni, compared to a control. Enriched nutrition by fiber addition significantly changed physical, chemical and cooking properties of rice-based gluten-free macaroni without diminishing sensory liking scores. Using rice flour as a major ingredient to develop high-value added gluten-free pasta products could potentially increase the economics of Thailand's rice industry.

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INTRODUCTION

Pasta is widely known as one of the main foods in western countries. Most of pasta products are made from durum wheat, semolina, and water. There are many products of pasta that are classified by shape such as spaghetti, tagliatelle, penne, fettuccine, bow tie, shells, spirali and lasagna included macaroni. Gluten is found in durum wheat, which is responsible for the formation of pasta structure. However, there is a growing rate of people who are sensitive to gluten. These people cannot consume wheat-based products (Moore et al., 2004). Celiac Disease (CD) is a response of body system when a genetically impressionable person consumes gluten-contained food. Antibody is released by autoimmune of body, which responses to gluten on villi and damage villi. It causes an inflammation and other symptoms such as diarrhea, illness, vomit, etc. The CD of 1% of total population is increased. Therefore, the only method to prevent CD is to avoid consuming foods contained of gluten. (Lamacchia et al., 2014). Curial et al. (2014) reported that the number of CD is increasing, affecting consumer demands for gluten-free products to grow. Typical gluten-free pasta is produced from flour and/or starch from rice, corn, sweet potato (or other tubers), with the addition of gums and protein, etc. which is functioned as substitutes for gluten (Marti and Pagani, 2013).

Rice is an important cultivated plant in Thailand. Its production represents a significant portion of Thai economy. Plai Ngahm Prachin Buri rice variety genetically produces more than 50% of chalkiness on rice kernel, which appeared at the middle of the grain (Lisle et al., 2000). Once passed the milling process to remove husk, the kernel of rice is easily broken due to chalkiness. These rice cannot be sold as whole grain, influencing rice farmers to selling at low prices. The quality of rice is dependent on rice physico-chemical characteristics that affect the price of rice as well (JICA, 2013). Therefore, chalky rice flour was used as a main ingredient for this research to formulate gluten-free pasta. Since tapioca starch could make the softness to product texture (Brites et al., 2018), thus a mixture of rice flour and tapioca starch was used. In general, consumption of traditional pasta as well as gluten-free pasta provides daily energy due to the presence of carbohydrate, protein and fat, while lacking an important nutrient like dietary fiber. The addition of dietary fiber for enriched nutrition is the best of choice although it could subtract desirable product characteristics. Ministry of Public Health (1998) reported that the fiber content of Thai Recommended Daily Intakes (Thai RDI) for Thai consumers with age of 6 years and up, is 25 g/day. In 2000, American Association of Cereal Chemists (AACC) provided the definition of dietary fiber as eatable parts of plant or similar carbohydrates that are indigestible portion (resistant to digestion) in the human stomach and intestine. Dietary fiber includes oligosaccharides, polysaccharides, lignin and plant related substances.

Many food products have been fortified with fiber such as breakfast cereals and bakery products (Cho and Prosky, 1999; Nelson, 2001) including dairy products, beverage and meat products. Fiber addition in certain products was also reported to function for reducing fat content (Byrne, 1997; Martin, 1999). The addition of fiber in beverages yielded increased viscosity and stability (Bollinger, 2001). Favorable results have been obtained when adding fiber in breakfast cereals, bakery products, beverages and meat products (Dhingra, 2012). Addition of soluble and insoluble dietary fiber in pasta could promote the firmness of pasta. Cooked gluten-free pasta typically had overly soft texture, affecting consumer acceptance. Pasta quality resulted from biochemical composition of raw materials, cooking properties and textural characteristics of the product (Tudoric et al., 2002). The combination of fiber could change rheological behaviour, textural properties and sensory attributes of the end products (Dhingra, 2012). Various hydrocolloids have been investigated in gluten-free products to mimic functionality of gluten in order to improve the texture of gluten-free pasta and bread (Padalino et al., 2016). Nevertheless, dietary fiber promotes health benefit and enriched nutrition. Therefore, the objective of this study was to investigate the effect of dietary fiber addition on quality of gluten-free pasta. Cooking quality, textural properties, proximate analyses and sensory evaluation were determined.

MATERIALS AND METHODS

Raw materials

Paddy rice (cv. Plai Ngahm Prachin Buri) was purchased from Rice Department (Ministry of Agriculture and Cooperatives, Thailand). The husk and bran of rice were removed by milling machine (TV02, Natrawee Technology Co., Ltd., Chachoengsao, Thailand). Rice grain was milled using rotor mill (Rotor beater mill SR 300, Retsch Co., Ltd., Germany) to rice flour with 150 µm of particle size and kept in sealed plastic bag at 10°C until use. Tapioca starch (Pla Mang Gon, Tong Jan Ltd., Bangkok, Thailand) was purchased locally. Fiber sources were obtained as the following: wheat fiber (WF) (VITACEL, JRS PHARMA GmbH & Co. KG., Rosenberg, Germany), corn meal (CM) (BBI Co., Ltd., Bangkok, Thailand) and cellulose fiber (CF) (Alba fiber® C-200, Adinop Co., Ltd., Bangkok, Thailand). Xanthan gum was purchased from Chemipan Corporation Co., Ltd., Bangkok, Thailand. Propylene glycol alginate (PGA) was from DUCK LOID EF, Kikkoman Biochemifa Co., Ltd., Tokyo, Japan.

Study of addition of dietary fiber for gluten-free macaroni

Rice flour, tapioca starch, xanthan gum (XG), propylene glycol alginate (PGA) and two levels of dietary fiber sources were formulated to produce gluten-free macaroni (Table 1). A fixed concentration of 1% XG and 3% PGA was used in all formula. Dry ingredients (100-101.5 g mixture) were mixed together and then water was added at various levels (72.5-87.5 g). Dough was kneaded for 10 min until smooth and rested at room temperature for 15 min.

Table 1. Formula of rice-flour based macaroni.

Formula	Rice flour	Tapioca starch	WF	CM	CF
C	80	20	-	-	-
WF10	72	18	10	-	-
WF20	64	16	20	-	-
CM10	72	18	-	10	-
CM20	64	16	-	20	-
CF1	80	20	-	-	1
CF1.5	80	20	-	-	1.5

C: without added fiber macaroni; WF10: 10% wheat fiber added macaroni; WF20: 20% wheat fiber added macaroni; CM10: 10% corn meal added macaroni; CM20: 20% corn meal added macaroni; CF1: 1% cellulose fiber added macaroni and CF1.5: 1.5% cellulose fiber added macaroni.

The dough was then extruded as macaroni-shaped pasta using an extruded pasta machine (Regina wellness Marcato S.p.A., Italy). Gluten-free macaroni samples were placed in a tray dryer at 40°C for 50 min and frozen at -10°C until analyzed.

Determination of gluten-free macaroni

Cooking quality

The optimum cooking time (OCT) was determined using AACC Method 66-50 (AACC, 2000). Macaroni sample (25 g) was placed into a 500-ml beaker with 300 ml of boiling distilled water. Every 30 s during cooking, the core strand of the sample was observed by squeezing it between two glass plates. Once the core of the samples was disappeared, it indicated the OCT.

Cooking loss (CL) was evaluated by calculating the amount of solids loss in cooking water (AACC 16-50, 2000). Macaroni sample was cooked at OCT and the cooking water was evaporated to dryness in a hot air oven at 105°C for 12 h.

Water absorption (WA) was investigated by weighing macaroni before and after cooking. The cooking loss and water absorption of the macaroni samples were calculated using the following equations (1) and (2):

$$CL\ (\%) = [\text{weight of dried residue in cooking water}/\ \text{weight uncooked sample}] \times 100 \quad (1)$$

$$WA\ (\%) = [(\text{weight of cooked sample} - \text{weight of uncooked sample})/\ \text{weight of uncooked sample}] \times 100 \quad (2)$$

Color

The color of gluten-free macaroni samples was determined by using a Minolta Chroma-Meter CR-200 colorimeter (Minolta Corp., Ramsey, N.J., U.S.A.) with CIE L* a* b* system.

Textural properties

Textural properties of macaroni was determined by using Texture Analyzer TA.XT Plus (Stable Micro System Ltd., England) to analyze for firmness, work of shearing and stickiness. Macaroni was cooked at the optimal cooking time and texture analysis was conducted using a light knife blade (A/LKB-F). Each sample was repeated at least six times. Test parameters were 0.17 mm/s pre-test speed, 0.17 mm/s test speed and 10 mm/s post-test speed. The height of sample was approximately 11 mm. Distance was adjusted to a maximum of 10.5 mm.

Proximate analyses of gluten-free macaroni

The moisture, fat, protein, crude fiber and ash contents were determined following by the standard methods of AOAC (2000). Carbohydrate contents of samples were calculated using the following equations:

$$\text{Carbohydrate}\ (\%) = 100-(\text{moisture}+\text{fat}+\text{protein}+\text{crude fiber}+\text{ash}) \quad (3)$$

Sensory evaluation

Seven macaroni samples were evaluated (C, WF10, WF20, CM10, CM20, CF1 and CF1.5) by 9-point hedonic scale determination using 50 untrained panelists. Each macaroni sample was cooked at the optimal cooking time. After cooking, two pieces (~4 g) of macaroni samples were put into the plastic container and served with a separate container of sauce. Panelists were asked for testing macaroni without sauce to evaluate appearance, color, rice aroma, rice flavor, hardness and overall liking. After sauce being added to the macaroni, the panelists were then evaluated for flavor of rice, overall taste and overall liking.

Statistical analysis

Experiment was carried out for 3 replications. Data were expressed as means ± standard deviation. The data were also subjected to analysis of variance (ANOVA) and Duncan's multiple range tests using SPSS 12.0 for Windows. The significance level of $p \leq 0.05$ was considered significant difference among means.

RESULTS AND DISCUSSION

Cooking quality of gluten free macaroni

Optimum cooking time

The appearance of gluten free macaroni is shown in Figure 1. The texture of WF added macaroni was softer than other samples and the dough was easy to be extruded. The CF added macaroni was thicker than other macaroni samples. Appearance of CM added macaroni possessed yellow color, similar to commercial pasta products. Once cooked, macaroni without added fiber was break easily when compared with fiber added macaroni. The highest optimum cooking time (OCT) was obtained from 1 and 1.5% cellulose fiber added macaroni, which were 9.00±0.87 and 8.67±0.58 min, respectively. In contrast, the OCT of macaroni which added 10 and 20% wheat fiber were the lowest (6.17±0.29 and 5.83±0.76 min) ($p>0.05$). Increasing OCT was observed with the higher amount of fiber sources being added, except for wheat fiber macaroni (WF10 and WF20).

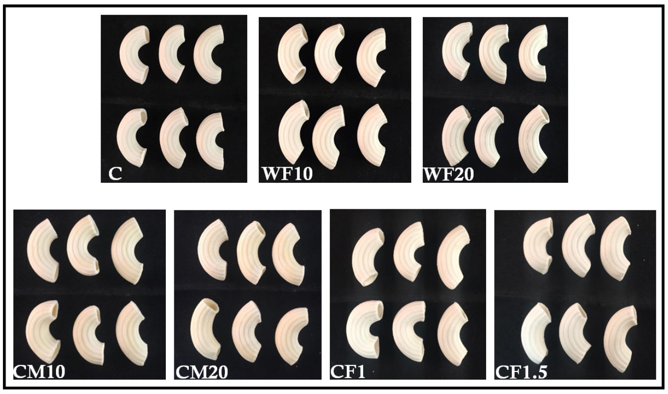

Figure 1. Appearance of gluten-free macaroni (C: without added fiber macaroni; WF10: 10% wheat fiber added macaroni; WF20: 20% wheat fiber added macaroni; CM10: 10% corn meal added macaroni; CM20: 20% corn meal added macaroni; CF1: 1% cellulose fiber added macaroni and CF1.5: 1.5% cellulose fiber added macaroni).

Cooking loss

The cooking loss (CL) of all macaroni samples ranged from 2.73±0.31 to 4.89±0.29% (Table 2). The relationship between amount of fiber sources being added and cooking loss of macaroni samples is presented in Figure 2a. Although the CL was increased when higher amount of the fiber was added, CL obtained from CF1 and CF1.5 were not significantly different ($p>0.05$). Menon et al. (2015) reported that the CL of spaghetti added with wheat fiber was higher than that of the control (no addition). The addition of other ingredients containing dietary fiber had an impact on loss of starch granules and/or solid particles during cooking, which resulted from an increase of loose texture of pasta (Del et al., 2005).

Table 2. Cooking quality of gluten-free rice-based macaroni.

Formula	Cooking time, OCT (min)	Cooking loss CL (%)	Water absorption WA (%)
C	7.83 ± 0.29^{b}	2.91 ± 0.03^{D}	105.08 ± 1.86^{b}
WF10	6.17 ± 0.29^{c}	2.73 ± 0.31D	96.37 ± 3.14^{cd}
WF20	5.83 ± 0.76^{c}	4.26 ± 0.14b	101.16 ± 1.91^{bc}
CM10	5.83 ± 0.58^{c}	3.65 ± 0.09c	94.99 ± 1.13^{d}
CM20	7.67 ± 0.5^{8B}	4.89 ± 0.29a	114.62 ± 0.55^{a}
CF1	8.67 ± 0.58^{AB}	3.99 ± 0.04b	117.42 ± 4.34^{a}
CF1.5	9.00 ± 0.8^{7A}	4.26 ± 0.15b	119.03 ± 5.18^{a}

C: without added fiber macaroni; WF10: 10% wheat fiber added macaroni; WF20: 20% wheat fiber added macaroni; CM10: 10% corn meal added macaroni; CM20: 20% corn meal added macaroni; CF1: 1% cellulose fiber added macaroni and CF1.5: 1.5% cellulose fiber added macaroni.

$^{a-d}$ Means in the same column with different letters expressed significant differences among samples (P≤0.05).

The decomposition of the pasta system was due to the presence of cereal grains which promoted the leaching of amylose or loss of solid during cooking (Tudorica et al., 2002). From Table 2, the highest CL was from CM20 as of 4.89±0.29%. In contrast, C and WF10 showed the lowest CL of 2.91±0.03 and 2.73±0.31%, respectively. Nevertheless, all macaroni samples were regarded as a good characteristic because the CL values were lower than 8% (Dick and Youngs, 1998).

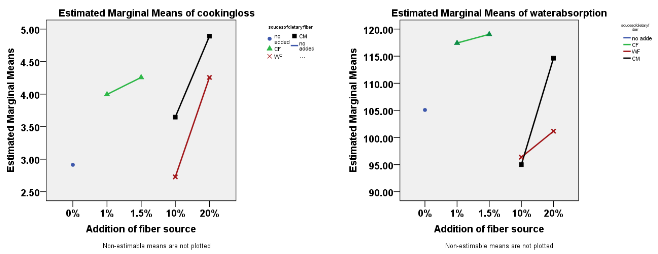

Figure 2. Relationship between addition of fiber source on cooking loss (a) and water absorption (b) of macaroni samples with added cellulose fiber (▲—▲), wheat fiber (×—×), corn meal (■—■) and not added fiber source (•).

Water absorption

From Figure 2b, water absorption (WA) of macaroni samples were increased when dietary fiber content increased. The CM20, CF1 and CF1.5 were the highest (114.62±0.55, 117.42±4.34 and 119.03±5.18%, respectively). Kaur et al. (2012) described the degree of gelatinization may be lower than without fiber. The network of starch was weak, that promotes the water to infiltrate into internal more easily.

Color parameter of gluten-free macaroni

Moisture content (31.0 to 34.5%) of macaroni with dietary fiber was higher than macaroni without dietary fiber (data not shown). The highest value on yellowness (b*) of 20% corn meal added macaroni (CM20) was 20.35±0.10. This formulation produced desirable yellow color on pasta appearance because corn meal is generally produced by yellow corn, which has yellow color from β-carotene pigment. The content of β-carotene in yellow corn is approximately 33.6 mg/100g (Singh et al., 2011). The b* value of other macaroni samples ranged from 6.82±0.12 to 7.69±0.19 (Table 3).

Table 3. Color parameter of gluten-free rice-based macaroni.

Formula	Color parameter		
	L*	a*	b*
C	87.59 ± 0.44^{a}	-0.09 ± 0.06^{CD}	6.82 ± 0.12^{D}
WF10	85.22 ± 0.12^{c}	-0.03 ± 0.03^{d}	7.57 ± 0.13^{c}
WF20	85.45 ± 0.58^{bc}	0.01 ± 0.04^{c}	7.53 ± 0.18^{c}
CM10	83.68 ± 0.55^{D}	0.21 ± 0.06^{B}	14.02 ± 0.40^{B}
CM20	77.01 ± 0.11^{E}	1.11 ± 0.11^{A}	20.35 ± 0.10^{A}
CF1	84.05 ± 0.47^{D}	-0.19 ± 0.02^{D}	7.67 ± 0.02^{c}
CF1.5	86.11 ± 0.13^{B}	-0.10 ± 0.06^{CD}	7.69 ± 0.19^{c}

C: without added fiber macaroni; WF10: 10% wheat fiber added macaroni; WF20: 20% wheat fiber added macaroni; CM10: 10% corn meal added macaroni; CM20: 20% corn meal added macaroni; CF1: 1% cellulose fiber added macaroni and CF1.5: 1.5% cellulose fiber added macaroni.

L* = Lightness, a* = redness, b* = yellowness

$^{a-e}$ Means in the same column with different letters expressed significant differences among samples (P≤0.05).

Textural properties of gluten-free macaroni

The texture properties are very important on consumer acceptance of food product. Results of firmness, work of shearing and stickiness are presented in Table 4. Firmness of CM20 and CF1.5 was the highest, which was similar to the control without fiber addition (C). The lowest firmness was observed on WF10 and WF20, which were 2.51±0.34 and 2.69±0.23 N, respectively. Menon et al. (2015) reported that spaghetti added with wheat fiber had less firm network than that of control, leading to soft pasta's texture (Del et al. 2005).

Table 4. Firmness, work of shearing and stickiness of gluten-free rice-based macaroni.

Formula	Firmness (N)	Work of shearing (g.cm)	Stickiness (g)
C	4.04 ± 0.40^{a}	90.99 ± 7.23a	-6.95 ± 3.0^{3a}
WF10	2.51 ± 0.34^{c}	55.01 ± 4.23^{d}	-9.98 ± 3.3^{9a}
WF20	2.69 ± 0.23^{c}	61.79 ± 4.70^{c}	-28.46 ± 3.84^{c}
CM10	3.07 ± 0.19^{b}	71.54 ± 5.60^{b}	-50.40 ± 19.64^{d}
CM20	4.17 ± 0.53^{a}	74.14 ± 7.32^{b}	-56.85 ± 8.8^{7d}
CF1	3.06 ± 0.37^{b}	71.20 ± 3.9^{5b}	-9.82 ± 2.9^{7a}
CF1.5	4.23 ± 0.38^{a}	95.21 ± 8.29^{a}	-17.27 ± 4.1^{6b}

C: without added fiber macaroni; WF10: 10% wheat fiber added macaroni; WF20: 20% wheat fiber added macaroni; CM10: 10% corn meal added macaroni; CM20: 20% corn meal added macaroni; CF1: 1% cellulose fiber added macaroni and CF1.5: 1.5% cellulose fiber added macaroni.

$^{a-d}$ Means in the same column with different letters expressed significant differences among samples (P≤0.05)

When WF was incorporated into the gluten-free macaroni, firmness was reduced much more than those from CM and CF. However, panelists provided similar liking scores on hardness attribute for the gluten-free pasta made of WF, CM and CF. Macaroni samples with the same source of fiber resulted in an increase of firmness when higher amount of fiber source was added in the formulation (Figure 3). Fiorda et al. (2013) studied gluten-free pasta made of 40% cassava bagasse which was high in fiber. As a result, firmness of high fiber added pasta increased. Moreover, there is an observation that increasing of firmness was probably from the characteristics of pre gelatinized flour that was high in water retention, which was also observed from a property of soluble dietary fiber. Tendency of stickiness was also similar to firmness.

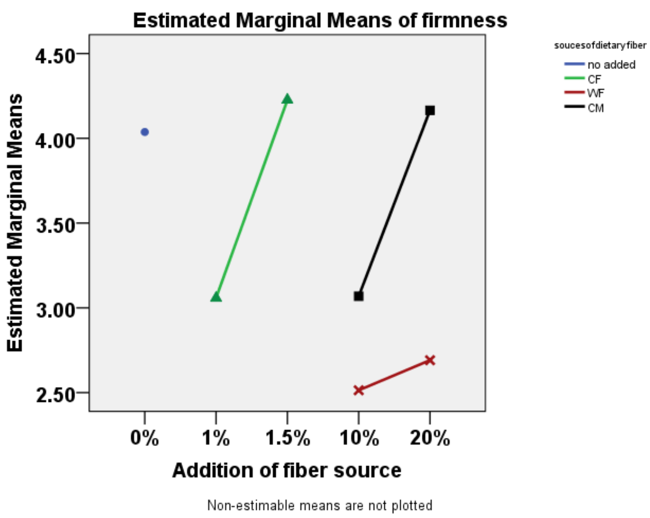

Figure 3. Relationship between addition of fiber source on firmness of macaroni samples with added cellulose fiber (▲—▲), wheat fiber (×—×), corn meal (■—■) and not added fiber source (•).

Zhao et al. (2005) investigated gluten-free spaghetti made from a combination of legume flours. The authors stated that cooking loss and firmness increased when legume flour was increased. Macaroni samples with dietary fiber addition were less firm than macaroni without dietary fiber. The addition of fiber influenced on diluted structures of pasta. Moreover, the composition of fiber has pectin which may be lost when cooking (solubilisation and leaching into water), leading to a decrease in firmness. Therefore, the cooked spaghetti had a soggy texture. (Menon et al., 2015). The highest work of shearing of C and CF1.5 were 90.99±7.23 and 95.21±8.29 g.cm, respectively.The WF10 formulation obtained the lowest work of shearing of 55.01±4.23 g.cm, which indicated that it was the easiest to be bitten when consuming. This would not be preferable by consumers since al dente is desire texture of pasta.

Sensory evaluation of gluten-free macaroni

Table 5 shows results on sensory evaluation of macaroni samples by 50 untrained panelists. Liking scores on appearance and color of CM10 and CM20 without sauce had the highest score (7.3 to 7.5). Overall liking score of CM10 was 7.0±1.1. When tasting without sauce, liking scores on rice flavor and hardness of gluten-free macaroni showed insignificant differences among all samples ($p>0.05$). However, panelists provided similar liking scores for all samples on rice flavor, overall taste and overall liking when tasted the samples with sauce ($p>0.05$). Macaroni samples (C, WF10, CM10 and CF1) were then selected for chemical composition analysis.

Macaroni with corn meal and without dietary fiber were not significantly different in crude fiber content ($p>0.05$). Crude fiber content of 10% wheat fiber and 1% cellulose fiber formulation had 10.1 and 1.9 times higher than that of C (no fiber added macaroni). Wheat fiber and cellulose fiber contained up to 97-99% of dietary fiber. On the other hand, corn meal had various chemical composition, especially containing a large amount of carbohydrate. Therefore, the crude fiber content of macaroni being added with corn meal was as low as macaroni without fiber addition. Lunn and Buttriss (2007) stated that the high content of dietary fiber could help the improvements on gastrointestinal health, glucose tolerance and insulin response, reduction of hyperlipidaemia, hypertension and other risk factors and help control weight body.

Table 5. Physical quality of calcium enriched fresh gluten-free pasta in pilot-scale.

Attribute	C	WF10	WF20	CM10	CM20	CF1	CF1.5
Taste before mixed with sauce							
Appearance	6.9 ± 1.2^{ab}	6.8 ± 1.3^{ab}	6.8 ± 1.3^{ab}	7.3 ± 0.9^{a}	7.3 ± 1.0^{a}	6.7 ± 1.3^{b}	6.9 ± 1.2^{ab}
Color	6.5 ± 1.2^{b}	6.5 ± 1.2^{b}	6.4 ± 1.3^{b}	7.4 ± 0.9^{a}	7.5 ± 0.9^{a}	6.4 ± 1.3^{b}	6.4 ± 1.4^{b}
Rice aroma	6.6 ± 1.3^{ab}	6.8 ± 1.1^{ab}	6.7 ± 1.2^{ab}	7.1 ± 1.1^{a}	6.9 ± 1.4^{ab}	6.4 ± 1.3^{b}	6.6 ± 1.4a^{b}
Rice flavor ^{ns}	6.5 ± 1.4	6.9 ± 1.0	6.7 ± 1.2	6.8 ± 1.2	6.6 ± 1.5	6.5 ± 1.4	6.4 ± 1.5
Hardness ^{ns}	6.3 ± 1.7	6.6 ± 1.4	6.5 ± 1.3	6.8 ± 1.3	6.5 ± 1.5	6.2 ± 1.5	6.6 ± 1.4
Overall liking	6.4 ± 1.3^{b}	6.7 ± 1.1^{ab}	6.4 ± 1.1^{b}	7.0 ± 1.1^{a}	6.8 ± 1.1^{ab}	6.3 ± 1.1^{b}	6.5 ± 1.2^{ab}
Taste after mixed with sauce							
Rice flavor ^{ns}	6.9 ± 1.0	6.9 ± 1.2	6.8 ± 1.4	7.0 ± 1.2	7.1 ± 1.1	6.8 ± 1.2	6.8 ± 1.2
Overall taste ^{ns}	7.1 ± 1.0	7.1 ± 1.3	7.0 ± 1.3	7.2 ± 1.2	7.1 ± 1.2	6.8 ± 1.3	7.1 ± 1.1
Overall liking ^{ns}	7.0 ± 1.1	7.0 ± 1.2	6.9 ± 1.3	7.2 ± 1.1	7.1 ± 1.2	6.7 ± 1.2	7.1 ± 1.1

C: without added fiber macaroni; WF10: 10% wheat fiber added macaroni; WF20: 20% wheat fiber added macaroni; CM10: 10% corn meal added macaroni; CM20: 20% corn meal added macaroni; CF1: 1% cellulose fiber added macaroni and CF1.5: 1.5% cellulose fiber added macaroni.

$^{a-b}$ Means in the same row with different letters expressed significant differences among samples ($P \leq 0.05$)
^{ns} Means in the same row were not significant different among samples ($P>0.05$)

Table 5. Physical quality of calcium enriched fresh gluten-free pasta in pilot-scale.

Chemical composition (%)	C	WF10	CM10	CF1
Moisture	24.66 ± 0.19^{d}	31.82 ± 0.16^{c}	32.66 ± 0.19^{b}	34.15 ± 0.28^{a}
Fat ^{ns}	0.20 ± 0.04	0.31 ± 0.01	0.32 ± 0.28	0.24 ± 0.05
Protein	1.13 ± 0.04^{a}	0.84 ± 0.00^{d}	1.03 ± 0.05^{b}	0.93 ± 0.07^{c}
Crude fiber	0.69 ± 0.11^{c}	6.97 ± 0.18^{a}	0.60 ± 0.18^{c}	1.32 ± 0.04^{b}
Ash	0.50 ± 0.01^{ab}	0.53 ± 0.04^{a}	0.47 ± 0.02B^{c}	0.44 ± 0.02^{d}
Carbohydrate	72.82 ± 0.32^{a}	59.80 ± 0.72^{d}	65.31 ± 0.81^{b}	63.85 ± 0.30^{c}

C: without added fiber macaroni; WF10: 10% wheat fiber added macaroni; WF20: 20% wheat fiber added macaroni; CM10: 10% corn meal added macaroni; CM20: 20% corn meal added macaroni; CF1: 1% cellulose fiber added macaroni and CF1.5: 1.5% cellulose fiber added macaroni.

$^{a-d}$ Means in the same row with different letters expressed significant differences among samples (P≤0.05)
^{ns} Means in the same row were not significant different among samples (P>0.05)

Proximate composition of gluten-free macaroni

Table 6 shows the moisture, fat, protein, crude fiber, ash and carbohydrate content of gluten-free rice-based macaroni. Fat content from C, WF10, CM10 and CF1 was not significantly different (p>0.05). Comparing among the dietary fiber added macaroni (WF10, CM10 and CF1), protein content of the corn meal added macaroni was the highest (1.03±0.05%) but it was lower than the control (C) without adding dietary fiber source. da Silva et al. (2016) reported that the protein content of corn meal flour and brown rice flour were 7.0% and 7.6%, respectively. However, they were not different significantly (p>0.05). As expected, the highest carbohydrate content of gluten-free rice-based macaroni was found in the formulation without dietary fiber addition (C) as of 72.82±0.32%. The main composition of gluten-free macaroni is rice flour, which was carbohydrate source. In comparison, the WF10 provided the highest crude fiber and ash content. Prominent amount of crude fiber (6.97±0.18%) was obtained when wheat fiber was substituted in the mixture of rice flour and tapioca starch. As a consequence, carbohydrate content was reduced in this formulation.

CONCLUSIONS

Various sources of dietary fiber were added to improve nutrition of gluten-free rice-based macaroni, which was mainly composed of carbohydrate (72.82±0.32%). Crude fiber was enhanced when adding wheat fiber and cellulose fiber to the gluten-free macaroni. The fiber sources influenced the cooking quality and textural properties of macaroni. Increasing the amount of fiber addition yielded higher values of cooking loss. All gluten-free macaroni in this study employed rice flour as a major ingredient and could be considered as good quality pasta. Sensory evaluation revealed that liking scores on appearance and color of corn meal added macaroni received the highest score (7.3 to 7.4) since it imparted natural yellow color from corn meal. Attributes on rice flavor, overall taste and overall liking were not significantly different among the tested macaroni and the liking scores were between like slightly and like moderately (p>0.05).

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