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Original Research Article

Development of calcium enriched rice pasta by extrusion process

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ABSTRACT

Chalky rice is not accepted by rice industry because of its appearance and brittleness. At present, many people are suffered for celiac disease so they have to avoid consuming foods with gluten. Rice flour can be used as a main ingredient for many Asian food products. It gives high energy, mostly from carbohydrate. The objectives of this study were to develop calcium enriched gluten free pasta by extrusion technology and to improve the pasta qualities. Four types of hydrocolloid (carboxy methyl cellulose; CMC, propylene glycol alginate; PGA, xanthan gum; XG and modified xanthan gum; MXG) were used in this study. The result indicated that 3.00% (w/w flour) MXG was not enough to form pasta dough, whereas a small amount (0.50%) of CMC, PGA or XG could form pasta shape with a laboratory-scale pasta extruder. By a pilot-scale twin screw extruder, only 0.30% of CMC, PGA or XG was needed to strengthen the pasta's firmness. Enhanced color could be obtained from a mixture of chalky rice flour and yellow corn flour at ratio of 70:30. Lightness (L*), redness (a*) and yellowness (b*) values of the fresh and cooked pasta was 54.52-73.76, 2.08-8.27 and 28.34-47.25, respectively. When adding calcium to the dry mixed flours, L*, a* and b* values of the extruded pasta were significantly decreased ($p \leq 0.05$). The formulation of pasta with 0.91% calcium and 0.30% PGA had the superior quality, compared to those with XG and CMC. It had the optimum cooking time of 12.67±0.29 min, the lowest cooking loss (9.20±0.70%), and the highest water absorption (62.96±3.81%). Water activity of fresh and dried pasta was 0.985±0.002 and 0.767±0.058, respectively. Firmness was 8.92±0.62 N. Sensory evaluation revealed that overall liking scores (6.88-7.14) of the pasta enriched with calcium at 20.00% and 50.00% Thai RDI (0.91% and 2.28%, respectively) were not significantly different ($p > 0.05$). By using extrusion process, the calcium enriched gluten-free pasta could be easily scale-up to the industrial scale due to technology availability. Moreover, unwanted chalky rice could be used as a main ingredient of the rice pasta, leading to economical aspect to the rice industry.

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INTRODUCTION

Rice is one of the typical staple foods worldwide because of its characteristics of white color, easy ability to digest and absence of gliadin, a part of gluten occurring in wheat (Arendt and Zannini, 2013). Rice is very important to Thai economy because Thailand is agricultural country which produces rice for both export and consumption in the nation. Rice varieties such as Ayutthaya 1, Plai Ngahm Prachin Buri, Prachin Buri 2 and Khao Bahn Nah possess unacceptable character of an opaque area called "chalkiness". The chalky rice is brittle and its appearance is unwanted to be consumed. Appearance of chalkiness on rice kernel is considered a defect leading to a decline of its price (Oupkaew and Wannavijit, 2016). Therefore, chalky rice is typically processed into rice flour. Chalky rice flour might be used to substitute wet-milled rice flour, which is used for many Asian food products. An increase on chalky rice flour value would be obtained if it is able to be employed for noodle or pasta production.

At present, many people are suffered from celiac disease approximately 1.00% of population around the world (Jafari *et al*., 2017). The patients have to avoid consumption of any foods containing gluten. A significant amount of rice flour has been reported for its effectiveness to replace wheat flour in many foods. However, only rice flour cannot be able to form pasta dough. Hydrocolloid is necessary to be added to improve quality of gluten-free product. Sanguinetti et al. (2015) studied effects of xanthan gum (XG) at 1.50–2.50% in gluten-free fresh filled pasta. The result indicated that dough was firm and elastic. Moreover, it was accepted to keep in a refrigerator for 14 days. Peressini et al. (2011) studied the results of XG and propylene glycol alginate (PGA) at 0.00, 0.50, 1.00 and 1.50% that was supplemented in rice-buckwheat batters. PGA resulted in low viscosity and elasticity of batters. Furthermore, PGA was able to form elastic films at the gas-liquid interface that aided stable gas cell. Thus, PGA affected high quality of breads which provided higher specific volume, mechanical properties and structure of crumb than those of XG. Furthermore, PGA was able to form elastic films. Liu et al. (2018) studied carboxyl methyl cellulose (CMC) and XG usage (0.50, 1.00 and 2.00%) in gluten-free potato steamed bread. The study showed an increase on gelatinization temperature and water absorption due to hydrocolloid adding. Hydrocolloid also affected on increasing of specific volume, while decreasing hardness. Choy et al. (2012) investigated the effect of CMC in instant fried noodle. Cooked instant noodle with added CMC increased in hardness and decreased in adhesiveness. When noodle was observed for its structure by scanning electron microscopy, fried instant noodle showed fewer voids than the control sample. Wang et al. (2016) studied synthesis and characterization of modified xanthan gum (MXG) from xanthan gum (XG) with poly (maleic anhydride/1-octadecene) (PMAO), compared with XG. Properties of MXG had higher viscosity, more compatible with salts, and more stable to shear and heat than those of XG. MXG could be used in food, personal care, etc.

Pasta normally provides high energy which is mostly from carbohydrate. Enrichment with specific nutrients would positively add value to pasta. National Diet and Nutrition Survey (NDNS) reported that British teenager consumed calcium approximately 80.00% of Reference Nutrient Intake (RNI) and 10.00–20.00% of teenager consumed calcium lower than the Lower Reference Nutrient Intake (LRNI). Not only teenager received calcium below the LRNI but also women aged of 19-24 years. Calcium is essential for healthy of bones and teeth. Calcium also plays a role on intracellular calcium, blood clotting, digesting, neurological and muscular function (Theobald, 2005). Moreover, calcium is found in dairy product, bakery, snack, etc. but a few meal products are found in the market (Mintel, 2018). The objective of this study was to develop calcium enriched gluten-free pasta that made from chalky rice flour (Ayuttaya 1). The study was divided into 2 parts which the first part studied the suitable type and amount of hydrocolloid during forming of the pasta dough with calcium enrichment in laboratory-scale where only cooking quality was concerned; the second part was to study in pilot-scale using extrusion technology. Chalky rice pasta was formulated by investigating suitable type and concentration of hydrocolloid as well as the study on proper quantity of calcium addition.

MATERIALS AND METHODS

Raw materials for pasta preparation

Chalky rice (Ayuttaya 1) was used in this study. The husk and bran layers of paddy rice were removed (Milling machine TV02, Natrawee Tecnology Co., Ltd., Chachoengsao, Thailand) and were dry-milled by pin mill (Bonny YTP-302S, Yor Yong Hah Heng Ltd., Bangkok, Thailand). Particle size of rice flour was less than 500 µm (moisture content 10.51±0.12%, ash 0.45±0.06%, protein 6.82±0.18%, fat 0.33±0.13%, crude fiber 0.92±0.08% and carbohydrate 80.97±0.15%). Chalky rice flour (CF) was kept in plastic bag at 10ºC. Commercial pasta available in the market is typically made from semolina leading to yellow color, therefore; the formulated gluten-free pasta in this study was incorporated by yellow corn flour (YCF) (BBI Co., Ltd., Bangkok, Thailand). YCF was stored in aluminium foil bag and kept at 10ºC until used. Calcium used in this study was Aquamin-F powder (Marigot Ltd, Strand Farm Currabinny, Carrigaline, Cork, Ireland). Aquamin-F is extracted from seaweed (Lithothamnion sp.). Quantity of calcium is 32.00%.

Four hydrocolloids were studied in formulating gluten-free pasta. Pasta was added by propylene glycol alginate (PGA) (Duck Loid EF, Kikkoman Biochemifa Company, Tokyo, Japan), xanthan gum (XG) (Central Gel Co., Ltd., Saraburi, Thailand), carboxyl methyl cellulose (CMC) (Yutai Orient Field Chemical Industry Co., Ltd., Shandong, China), modified xanthan gum (MXG) (Central Gel Co., Ltd., Saraburi, Thailand).

Laboratory scale pasta production

The samples from laboratory-scale production were evaluated for an ability to forming the dough and cooking quality of pasta. Different types of hydrocolloid with and without calcium addition were investigated. Calcium was added at 15.00% Thai Recommended Daily Intakes (Thai RDI). Formulas were prepared according to Table 1. Hydrocolloid was mixed with calcium before chalky rice flour (CF) was added. After all ingredients were mixed, distilled water (70 g) was added slowly in flour and kneaded. Dough was rested for 10.00 min in a closed container at room temperature. After that, dough was pressed through large macaroni die by extruded pasta machine (Regina wellness Marcato S.p.A., Italy).

Table 1. Laboratory scale formulation of pasta.

Pasta code	Chalky rice flour (CF) (g)	Hydrocolloid (%)		Calcium (%)
PGA	100	PGA	0.50	0.00
PGA-Ca	100	PGA	0.50	0.69
XG	100	XG	0.50	0.00
XG-Ca	100	XG	0.50	0.69
CMC	100	CMC	0.50	0.00
CMC-Ca	100	CMC	0.50	0.69
MXG	100	MXG	3.00	0.00
MXG-Ca	100	MXG	3.00	0.69

Samples from extrusion were evaluated for cooking quality that was determined according to AACC approved method 66-50 (AACC, 2000). Pasta (25 g) was cooked in 300 ml distilled water. Pasta was sampled every 30 s. Optimum cooking time (OCT) was evaluated as the time that the dry central core of pasta disappear when it was squeezed between two glass plates. Cooked pasta at OCT was weighed to calculate water absorption. Water from pasta boiling was contained in consistent weight beaker and was dried to constant weight at 105±2ºC. Results of cooking quality were the average of at least 3 replicates for each sample.

$$\text{Water absorption} = \frac{(\text{weight of cooked pasta} - \text{weight of uncooked pasta}) \times 100}{\text{weight of uncooked pasta}}$$

$$\text{Cooking loss} = \frac{(\text{weight of dried pasta boiled water}) \times 100}{\text{weight of uncooked pasta}}$$

Pilot scale pasta forming by extruder

Pasta forming by a twin screw extruder (Hermann Berstorff Laboratory, ZE 25x33D, Quakenbrück, Germany) was studied in two parts. First part, pasta was added with 0.30% of hydrocolloid and 0.91% of calcium (20.00% Thai RDI). Inside an extruder, material is transported, mixed and plasticized while generating frictional heat, pressure and shear (Rosentrater and Evers, 2018). This allows the usage of hydrocolloid at minimum level, comparably lower amount than laboratory scale production. Since the commercial pasta appears yellow, color of gluten-free pasta was enhanced by using a mixture of chalky rice flour and yellow corn flour at a ratio of 70:30. Cappa et al. (2017) substituted corn flour of 29.40–65.30 g/100g in frozen gluten-free pasta.

CF, YCF, hydrocolloid and calcium (Table 2.) were mixed by a mixer (KitchenAid, model K5 ss, St. Loseph, USA) and fed into the extruder. Barrel temperatures of each zone were controlled at 30, 45, 75, 70, 80, 100 and 80°C, respectively. Feed moisture content was 40.00% and screw speed was at 150 rpm. Pasta exiting the die (diameter of 2 mm) was spaghetti shape. Fresh pasta was cut into 25.00 cm length before packing in plastic bag and kept at -18°C. Frozen pasta was thawed before quality evaluation. Cooking quality of the pasta was evaluated and water activity was measured by Aqua LAB instrument (Aqua LAB, Model Serie 3TE, Washington, USA).

Fresh and cooked pasta were analyzed for moisture content and color. Moisture content was determined according to the official standard methods (AOAC, 2000). Pasta samples ~3 g were weighed and placed in moisture can and then heated in a hot air oven (Binder, model FD 115, Tuttlingen, Germany) at 105±2°C for at least 3 h to constant weight. Color of pasta was determined by a spectrophotometer (Minolta, model CM-3500d, Aichi, Japan) using the CIE L*a*b* system, 10º standard observer and D65 light source. Color parameter was reported as lightness (L*), redness (a*) and yellowness (b*).

Pasta made of mixed flour between CF and YCF was coded as M, while a control containing only CF was coded as R. Different types of hydrocolloid were investigated at a fixed concentration at 0.30% and calcium was added at 0.91% (Table 2.).

Table 2. Pilot scale formulation of pasta.

Pasta code	Chalky rice flour (CF) (g)	Yellow corn flour (YCF) (g)	Hydrocolloid (%)		Calcium (%)
R(PGA-Ca)	100	-	PGA	0.30	0.91
M(PGA)	70	30	PGA	0.30	-
M(PGA-Ca)	70	30	PGA	0.30	0.91
M(XG-Ca)	70	30	XG	0.30	0.91
M(CMC-Ca)	70	30	CMC	0.30	0.91

The second part for pilot scale study was to examine two levels of calcium addition. The formula obtained from the first part with superior quality was then added with calcium at 0.00, 0.91 and 2.28% (0.00, 20.00 and 50.00% Thai RDI, respectively). Fresh pasta was dried in tray dryer (Frecon, BWS-model, B.W.S Trading, Ltd., Bangkok, Thailand) at 45°C for 4 h. Samples were packed in aluminum foil bag and stored at room temperature. Dried pasta was measured for quality following the first part.

Furthermore, samples were analyzed for firmness according to AACC approved method 66-50.01 (AACC, 2010). Samples were cooked at OCT. Cooked pasta was rested in closed container for 10.00 min. Texture Analyzer (TA.XT Plus, Stable Micro System, Guildford, England) was calibrated and set for a pre-test speed of 1.00 mm/s, test-speed of 0.50 mm/s, post-test speed of 10.00 mm/s, distance of 8.00 mm and trigger force of 0.05 N. Samples (5 pieces) were placed on stage and cut by A/LKB-F knife. Results were the average of at least 15 replicates.

The sensory evaluation was conducted with 50 untrained panelists. Three pasta samples were evaluated on liking score by a 9-point hedonic scale (1 means dislike extremely, 9 means like extremely). Panelists were asked to provide liking scores on appearance, color, rice odor, rice flavor, overall texture and also asked if they noticed any aftertaste when testing pasta without sauce. After that, they evaluated for overall flavor, overall liking and aftertaste when serving the pasta with sauce.

Dried pasta was analyzed for chemical compositions of moisture (AOAC (2016) 950.46 (B)), ash (AOAC (2016) 920.153), protein (in-house method TE-CH-042 based on AOAC (2016) 981.10), fat (AOAC (2016) 922.06) and carbohydrate (in-house method TE-CH-169 based on Compendium of Methods for Food Analysis Thailand, 1st Edition, 2003) and analyzed for quantity of calcium (in-house method TE-CH-134 based on AOAC (2016) 984.27 by ICP-OES). The chemical quality analyses were done by Central Laboratory (Thailand) Co., Ltd., Bangkok, Thailand.

Statistical analysis

Quantitative data were expressed as means ± standard deviation. Analysis of Variance (ANOVA) was performed. Duncan's multiple range tests was analyzed using SPSS 12.0 (IBM Thailand Co., Ltd., Bangkok, Thailand) for Windows. The significance level of $p \leq 0.05$ was considered significantly different.

RESULTS AND DISCUSSION

Laboratory scale pasta production

The samples were evaluated for the dough forming of calcium added rice pasta by using different hydrocolloids. Eight formulas were added with four hydrocolloids (PGA, XG, CMC and MXG) at a fixed concentration in the absence and presence of calcium (0.00 and 0.69% for 0.00 and 20.00% Thai RDI, respectively). Dough was pressed through large macaroni die in laboratory-scale pasta machine. The results indicated that use of 3.00% MXG was unable to form pasta dough, whereas a small amount of 0.50% PGA, XG or CMC could produce gluten-free pasta. Wang et al. (2016) reported that solution containing MXG had more viscosity with better performance on salt tolerance, temperature resistance, and shear endurance than XG. However, the results from laboratory-scale pasta forming using dry mix could not observe the advantage of MXG.

Pasta was prepared formed dough and was measured for cooking quality. Both no calcium and calcium added pasta with different hydrocolloids (PGA, XG, CMC and MXG) were coded as PGA, PGA-Ca, XG, XG-Ca, CMC, CMC-Ca, MXG and MXG-Ca. Optimum cooking times (OCT) of these samples were 1.50-2.00 min (Table 3). CMC-Ca used the least time for cooking. Use of CMC resulted in weak structure of instant fried noodle (Choy et al., 2012). Cooking loss and water absorption was 1.38-3.01% and 54.61-60.30%, respectively. Optimal cooking time, cooking loss and water absorption of fresh semolina pasta that studied by Kim et al. 2017 was 1.30 min, 24.47% and 59.77%, respectively. Fois et al. (2018) indicated that OCT and cooking loss of fresh semolina pasta was 3.30 min and 3.34%, respectively. Low cooking loss is typically used as an indicator of high quality pasta. Calcium added pasta had no significant difference on cooking loss from no calcium adding.

Table 3. Cooking quality of gluten-free pasta from chalky rice flour (CF) in laboratory-scale.

Pasta code	Optimum cooking time (OCT) (min)	Cooking loss (%)	Water absorption (%)
PGA	2.00±0.00	3.01±1.48^{a}	54.61±1.57^{b}
PGA-Ca	2.00±0.00	1.59±0.10^{ab}	60.30±2.80^{a}
XG	2.00±0.00	1.38±0.04^{b}	55.28±1.32^{b}
XG-Ca	2.00±0.00	1.44±0.09^{ab}	57.17±0.56^{ab}
CMC	2.00±0.00	1.92±1.30^{ab}	59.72±2.92^{a}
CMC-Ca	1.50±0.00	2.33±0.17^{ab}	55.10±2.50^{b}
MXG	-	-	-
MXG-Ca	-	-	-

Values are expressed as means ± SD (n=3).
Different letters in the same column indicate significant difference at $p \leq 0.05$.

Pilot scale pasta forming by extruder

In pilot-scale, the study was divided into two parts. First part, forming of calcium enriched fresh pasta was studied by extruder. After hydrocolloids were investigated in laboratory-scale, they were chosen to study in pilot-scale, i.e. PGA, XG and CMC. Pasta was added with calcium at 0.91% (20.00% Thai RDI) (M(PGA-Ca), M(XG-Ca) and M(CMC-Ca)). This level of calcium could be claimed as calcium enriched pasta. In addition, enhanced color of pasta could be obtained from incorporation of YCF at 30.00%. Forming with extruder used only 0.30% of hydrocolloid. This amount was enough to form pasta shape because extrusion renders high temperature, pressure and shear to aid forming (Rosentrater and Evers, 2018). The results were compared with pasta used only 100.00% chalky rice flour (R(PGA-Ca)) and pasta with no added calcium (M(PGA)).

Table 4 shows cooking quality. Chalky rice flour (100.00%) (R(PGA-Ca)) had the highest OCT (23.33±0.29 min). When using mixed flour between chalky rice flour and yellow corn flour at the ratio of 70:30, lower OCT was observed than that of using 100.00% rice flour. M(PGA-Ca) spent more time for cooking than M(XG-Ca) and M(CMC-Ca), respectively. Water absorption of R(PGA-Ca), M(PGA) and M(PGA-Ca) was the highest and insignificant difference. Cooking loss of M(XG-Ca) and M(CMC-Ca) was in the range of 20.52–25.96%, which was significantly higher than that of M(PGA-Ca). Water absorption was 59.77–62.70% (Kim et al., 2017). Cooking loss of pasta is accepted at below 8.00% and must not be more than 10.00% (Lucisano et al., 2012; Phongthai et al., 2017). Furthermore, pasta without calcium (M(PGA)) and calcium enriched pasta (M(PGA-Ca)) were not different significantly on all attributes of cooking quality. Cooking quality is generally used to indicate pasta quality. The results showed that PGA provided the superior quality when used in gluten-free pasta.

Table 4. Cooking quality of fresh gluten-free pasta from chalky rice flour (CF) in pilot-scale.

Sample	Optimum cooking time (OCT) (min)	Cooking loss (%)	Water absorption (%)
R(PGA-Ca)	23.33±0.29^{a}	5.94±0.21^{d}	67.28±3.79^{a}
M(PGA)	12.50±0.50^{b}	7.98±1.79^{cd}	71.34±3.31^{a}
M(PGA-Ca)	12.67±0.29^{b}	9.20±0.70^{c}	62.96±3.81^{a}
M(XG-Ca)	11.67±0.58^{c}	20.52±2.33^{b}	27.44±4.04^{b}
M(CMC-Ca)	9.83±0.29^{D}	25.96±1.28^{a}	23.80±8.69^{b}

Values are expressed as means ± SD (n=3).
Different letters in the same column indicate significant difference at $p \leq 0.05$.

Water activity (a_w) of fresh pasta was 0.983-0.989 (Table 5.). It indicated that microorganism can use free water in product for growth (Safefood 360, 2014) so it must store at either chilled temperatures (-3 to 7ºC) or frozen (-18ºC). Fois et al. (2018) studied fresh pasta from semolina and reported a_w of 0.960-0.977. In addition, Carini et al. (2009) stated that a_w of fresh durum wheat semolina pasta from extruder was 0.983.

For moisture content of pasta, fresh pasta samples from extruder had moisture content in the range of 34.52-38.31%. When samples were cooked at OCT, moisture content increased to 50.47-68.00%. Moisture content of gluten-free potato-based pasta was 49.60-64.80% and 53.24-68.10% on fresh and cooked fresh pasta, respectively (Cappa et al., 2017).

When measured for color in CIE L*a*b* system, lightness (L*), redness (a*) and yellowness (b*) values of the fresh pasta was 54.52-61.03, -0.65-8.27 and 17.27-47.25, respectively. L*, a* and b* values of cooked fresh pasta was 69.20-74.40, -0.90-3.43 and 12.56–30.83, respectively. L* value of cooked pasta was higher than that of fresh pasta. On the other hand, a* and b* values were lower than those of fresh pasta. When pasta was substituted by YCF, L* value was decreasing, a* and b* values were increasing. M(PGA) had significantly higher a* and b* values than M(PGA-Ca) ($p \leq 0.05$). This trend was also observed on cooked fresh pasta. Fois et al. (2018) showed L*, a* and b* values of raw semolina pasta of 76.06-80.22, 1.39-1.71 and 28.79–34.33, respectively.

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

Sample	Fresh pasta					Cooked fresh pasta			
	Moisture content	Water activity	Color			Moisture content	color		
	(%)	(a_w)	L*	a*	b*	(%)	L*	a*	b*
R(PGA-Ca)	34.52±0.37^{D}	0.983±0.003^{c}	61.03±0.18^{a}	-0.65±0.18^{d}	17.27±0.17^{e}	68.00±4.54^{a}	74.40±1.18^{a}	-0.90±0.1^{0d}	12.56±0.19^{c}
M(PGA)	38.31±0.02^{A}	0.988±0.001^{ab}	60.29±0.47^{b}	8.27±0.05^{a}	47.25±0.88^{a}	64.07±1.08^{ab}	73.76±0.17^{ab}	3.43±0.13^{a}	30.83±0.4^{1a}
M(PGA-Ca)	36.82±0.07^{c}	0.985±0.002^{bc}	54.52±0.51^{d}	6.16±0.16^{c}	38.67±0.10^{d}	50.47±5.16^{c}	69.20±0.61^{d}	2.57±0.14^{b}	29.38±1.12^{b}
M(XG-Ca)	37.04±0.25^{c}	0.988±0.002^{a}	55.26±0.39^{c}	6.58±0.10^{b}	40.20±0.04^{b}	60.02±2.01^{b}	71.74±0.30^{c}	2.50±0.0^{3b}	28.34±0.29^{b}
M(CMC-CA)	37.69±0.19^{B}	0.989±0.001^{a}	55.73±0.23^{c}	6.28±0.15^{c}	39.46±0.14^{c}	62.14±2.30^{ab}	72.98±0.19^{b}	2.08±0.03^{c}	29.02±0.2^{2b}

Values are expressed as means ± SD (n=3).
Different letters in the same column indicate significant difference at $p \leq 0.50$.

After pasta forming was studied by different hydrocolloids in pilot-scale, the study of calcium levels was performed in the second part. PGA yielded the best cooking quality, compared to other hydrocolloids. Therefore, PGA added pasta was enriched with calcium at 0.00, 0.91 and 2.28% (0.00, 20.00 and 50.00% Thai RDI, respectively) namely M(PGA), M(PGA-Ca 20) and M(PGA-Ca 50). Samples from extruder were further dried to extend shelf life.

Table 6 shows cooking quality of dried pasta (with and without calcium). OCT of sample increased when quantity of calcium increased (19.50–20.67 min). Cooking loss of pasta was 9.45–15.02%. Water absorption was not significant difference (p>0.05) (99.36–111.89%). Cooking loss and water absorption of dried rice-based pasta were 4.20–15.90% and 61.80–75.90%, respectively (Marti et al., 2010). Dried semolina pasta from Gatta et al. (2017) had OCT 11.30 min, cooking loss 6.04% and water absorption 154.00%. Commercial durum wheat pasta was 8.00–11.00 min of OCT, 4.24–7.08% of cooking loss and 150.00–178.00% of water absorption (Ficco et al., 2016). Cooking loss of calcium enriched rice pasta from this study was closed to the dried rice-based pasta but water absorption was higher.

Compared to dried semolina pasta and commercial durum wheat pasta, both values of cooking loss were lower and water absorption was higher than those of calcium enriched pasta.

Table 6. Cooking quality of dried gluten-free pasta from chalky rice flour (CF) in pilot-scale.

Sample	Optimum cooking time (OCT) (min)	Cooking loss (%)	Water absorption (%)
M(PGA)	19.50±0.50^{b}	15.02±0.20^{a}	111.89±10.92^{a}
M(PGA-Ca 20)	20.50±0.50^{ab}	9.45±2.01^{b}	99.36±13.89^{a}
M(PGA-Ca 50)	20.67±0.58^{a}	14.09±0.46^{a}	100.16±12.44^{a}

Values are expressed as means ± SD (n=3).

Different letters in the same column indicate significant difference at $p \leq 0.05$.

The results of aw of dried pasta are presented in Table 7. It was 0.747–0.767. Water activity of dried pasta could be 0.500–0.600 (Safefood 360, 2014). Although aw of samples was higher than the recommended level, this range of 0.747–0.767 could not promote bacterial growth. Dried pasta had moisture content of 13.61–13.79%. After pasta was cooked, moisture content increased to 61.72–65.62%. Even though, pasta from this study had moisture content more than 12.50% (Alamprese, 2017), the moisture content was decreased significantly after drying when compared to fresh pasta after exiting the extruder's die.

Sample was measured for color (L*, a* and b* value) of dried pasta, which was 52.01–56.70, 7.92–10.91 and 40.52–49.88, respectively. When pasta was cooked, L* value increased to 67.50–73.29, a* and b* values decreased to 2.16–2.65 and 26.28–29.14, respectively. The results indicated that L*, a* and b* value decreased, when calcium level increased. Phongthai et al. (2017) studied dried protein enriched rice flour pasta and reported L*, a* and b* value of 49.69–82.04, -0.69–7.44 and 7.85–16.40, respectively.

Pasta samples were measured for firmness by Texture Analyzer. The sample was added with calcium at 0.00, 0.91 and 2.28%. The results were compared with 2 commercial product samples which were rice-based pasta. Firmness of samples was 7.43–10.05 N. When increased calcium content, firmness increased significantly (p≤0.50) (Table 8).

Phongthai et al. (2017) studied the effects of protein enrichment on gluten-free rice pasta. Firmness was 0.81–2.19 N. Commercial rice pasta had lower firmness than calcium enriched gluten-free rice pasta. In addition, the commercial pasta samples had firmness about 5.80–7.80 N (Bruneel et al., 2010). When measured firmness of 2 rice pasta products in Thai local market, firmness of both commercial pasta were not significant difference (2.11-2.24 N) (p>0.05). However, the firmness of commercial products showed lower values than rice pasta samples in this study. Table 8 shows that dried calcium enriched gluten-free pasta had significantly higher firmness than the rice pasta with PGA only (p≤0.50).

Table 7. Physical quality of calcium enriched dried gluten-free pasta in pilot-scale.

Sample	Dried pasta					Cooked dried pasta			
	Moisture content	Water activity	Color			Moisture content	color		
	(%)	(a_w)	L*	a*	b*	(%)	L*	a*	b*
M(PGA)	13.79±0.61[a]	0.753±0.115[b]	56.70±0.15[a]	10.91±0.16[a]	49.88±0.13[a]	65.62±0.56[a]	73.29±0.07[a]	2.65±0.08[a]	29.14±0.14[a]
M(PGA-Ca 20)	13.63±0.16[a]	0.767±0.058[a]	52.01±0.08[c]	9.01±0.16[b]	43.40±0.15[b]	61.72±1.07[b]	67.97±0.20[b]	2.41±0.12[b]	28.05±0.47[b]
M(PGA-Ca 50)	13.61±0.50[a]	0.747±0.058[c]	53.38±0.18[b]	7.92±0.02[c]	40.52±0.06[c]	63.10±2.09[ab]	67.50±0.12[c]	2.16±0.08[c]	26.28±0.34[c]

Values are expressed as means ± SD (n=3).

Different letters in the same column indicate significant difference at p ≤ 0.50.

Table 8. Firmness of calcium enriched dried gluten-free pasta and commercial pasta.

Sample	Firmness (N)
M(PGA)	7.43±0.88[c]
M(PGA-Ca 20)	8.92±0.62[b]
M(PGA-Ca 50)	10.05±0.60[a]
Commercial product 1	2.24±0.12[d]
Commercial product 2	2.11±0.19[d]

Values are expressed as means ± SD (n=15).

Different letters in the same column indicate significant difference at p≤0.05.

For sensory evaluation, samples added with calcium at 0.91 and 2.28% were served simultaneously with the sample without calcium addition. Fifty panelists evaluated sensory attributes by using 9-point hedonic scale. The result indicated that all attributes (appearance, color, rice odor, rice flavor, overall texture, overall flavor and overall liking) were not significant difference (p>0.05). Overall liking had score of 6.9−7.1 that means like slightly to like moderately. When panelists evaluated calcium added pasta without sauce, 82.00% of panelists could not detect aftertaste. On the other hand, some panelists (18.00%) perceived smell of rice and felt grainy texture. A majority of panelists (77.80%) who observed the aftertaste at the first time did not feel aftertaste when consuming pasta with sauce.

Table 9. Pilot scale formulation of pasta.

Attribute		Liking score		
		M (PGA)	M (PGA-Ca 20)	M (PGA-Ca 50)
Evaluate only pasta	Appearance	7.2±1.3[a]	7.0±1.4[a]	7.1±1.2[a]
	yellowness	7.3±1.2[a]	7.2±1.2[a]	7.3±1.0[a]
	Rice odor	6.9±1.2[a]	6.7±1.3[a]	6.8±1.1[a]
	Rice flavor	6.7±1.1[a]	6.6±1.2[a]	6.5±1.1[a]
	Overall texture	6.7±1.2[a]	6.2±1.6[a]	6.5±1.2[a]
Evaluate pasta with sauce	Overall flavor	7.1±1.3[a]	6.8±1.3[a]	7.0±1.1[a]
	Overall liking	7.1±1.3[a]	6.9±1.2[a]	7.1±1.0[a]

Values are expressed as means ± SD (n=50).

Different letters in the same row indicate significant difference at p≤0.05.

Pasta sample (M(PGA-Ca 20) was analyzed for chemical composition by Central Laboratory. It had moisture, ash, protein, fat and carbohydrate of 15.44, 1.23, 7.18, 1.41 and 74.74%, respectively. When analyzed quantity of calcium, M(PGA-Ca 20) had calcium of 3017.64 mg/kg of pasta (equivalent to 20.75% Thai RDI). This could claim that the developed pasta was an excellent source of calcium. In addition, M(PGA-Ca 50) had calcium of 8284.02 mg/kg of pasta (equivalent to 56.95% Thai RDI). Consumers would receive enough calcium in a day, if they consume M(PGA-Ca 50) for 2 serving sizes (55 g of dried pasta/ serving size).

CONCLUSIONS

Hydrocolloids (PGA, XG and CMC) were subjected to calcium enriched gluten-free chalky rice pasta, which could successfully form pasta dough in laboratory-scale at minimum concentration of 0.50%. When pasta was developed in pilot-scale using extrusion, PGA provided superior quality due to low cooking loss and high water absorption. With increasing calcium in gluten-free rice-based pasta, firmness increased significantly. L*, a* and b* decreased when calcium was enriched at the higher level. Sensory evaluation revealed that the liking scores of each attribute was between “like slightly” and “like moderately”. M(PGA-Ca 20) could be claimed for an excellent source of calcium. By consuming M(PGA-Ca 50) for 2 serving sizes (55 g of dried pasta/serving size) per day, consumers would obtain the required amount of calcium following the recommendation from Ministry of Public Health of Thailand.

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