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Improvement process of partially cooked corn grit (PCCG) preparation

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Abstract

Steamed corn grits, or *nasi jagung*, is an indigenous, corn-based product, which is usually used to substitute rice, particularly in the central part of Java and Madura regions, Indonesia. However, there is limited information regarding the preparation of partially cooked corn grits (PCCG). The objective of the present work was therefore to compare the preparation of PCCG in terms of characteristics and time of preparation using optimised initial moisture content in the traditional process with optimised corn particle size, initial moisture content and processing temperature of the improved process. Water absorption index (WAI), water solubility index (WSI), yellowness index (YI), and resistant starch (RS) of dried PCCG, as well as textural properties of rehydrated PCCG, were compared between optimised PCCG prepared using traditional and improved processes to obtain the best PCCG. Results showed that the optimum initial moisture content to prepare PCCG by the traditional process was approximately 40%. The optimum conditions to prepare PCCG by the improved process were 300 µm corn particle size, 52.33% initial moisture content and 123.67°C processing temperature. PCCG prepared using the improved process had higher values of YI (99.51) and RS (3.65 g/100 g) but lower WAI value (3.74) than YI (95.78), RS (1.96 g/100 g) and WAI (3.96) of PCCG prepared using the traditional process. The textural properties of rehydrated PCCG, except for adhesiveness and cohesiveness, prepared using the improved process were not different from those of PCCG prepared using the traditional process. The improved process also had a shorter preparation time of PCCG, which was 4-6 h as compared to normally 3-4 d in the traditional process. Therefore, a more rapid process with more consistent qualities for preparing PCCG will be of benefit to the target population.

Introduction

Corn is the second most important grain after rice in Indonesia. Corn kernels consist of approximately 73% starch, 10% protein, 5% oil, fibre, vitamins and minerals. Although both rice and corn contain almost similar amount of calories, corn contains higher amounts of protein, minerals, vitamins and fibre (Nuss and Tanumihardjo, 2010). Because of its nutritional value, corn has been used as a source of carbohydrates to substitute rice. Steamed corn grits, locally known as *nasi jagung*, is one of the corn-based products consumed by people in Central Java and Madura regions, Indonesia. However, the time-consuming process of preparing ready-to-consume corn grits is rather inconvenient. The process takes approximately three to four days for the preparation, consisting of milling, two days of soaking, mixing to form the corn agglomerate, steaming, and sun drying (Indonesian Institute of Science, 2009). Consequently, people rarely consume steamed corn grits due to the long process of preparation and the undesirable flavour of the final product produced during soaking.

To prepare a convenient starch-based product, it is necessary to perform partial (≈80%) or complete

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(≈100%) gelatinisation (Al-Rabadi *et al.*, 2011). According to Brenda *et al.* (2014), gelatinisation has a strong effect on textural properties, which becomes the primary quality parameter of the final starch-based product. Gelatinisation is influenced by several factors, such as moisture content, the botanical source of starch, processes applied to starch before gelatinisation, amylose or amylopectin content of starch, temperature, and the cooking method. Prasert and Suwannaporn (2009) reported that high initial moisture content resulted in a softer texture of instant rice. Meanwhile, according to Al-Rabadi *et al.* (2011) and Yadav *et al.* (2014), the size of grits affected the physical and sensory properties of gelatinised pearl millet and sorghum. In addition, cooking at high temperatures has also been reported to result in more homogenous gelatinisation, and is the primary factor influencing the pasting properties of partially cooked rice (Prasert and Suwannaporn, 2009; Bhattacharya, 2011).

Previous studies have investigated various processes to produce convenient corn grits, such as the addition of lime and variation of boiling time (Sugiyono *et al.*, 2004; Wrasiati *et al.*, 2014), the use of various drying methods (Husain *et al.*, 2006; Hanjagi *et al.*, 2013), and the use of agglomerator and addition of fortified flour (Santoso and Novita, 2013; Azizah *et al.*, 2013). However, there is limited information regarding the process of preparing partially cooked corn grits (PCCG) traditionally. Therefore, it is necessary to determine the optimum initial moisture content of PCCG in the traditional process. The objective of the present work was therefore to compare the preparation of PCCG in terms of characteristics and time of preparation using optimised initial moisture content in the traditional process with those of optimized corn particle size, initial moisture content and processing temperature in the improved process.

Materials and method

Materials

Roughly milled yellow corn (Zea mays var. indurate Sturt) measuring 1.6 ± 0.2 mm in size with 9.6 ± 0.65% moisture content, was obtained from Pasar Borong Selangor, Selangor, Malaysia. This type of corn has been used by Central Java and East Java communities to produce their cooked corn grits in Selangor. The impurities were manually removed before further processing. Subsequently, the grits were stored in polypropylene vacuum bag at 12 ± 2°C until further usage.

Method

Traditional PCCG preparation with optimised initial moisture content

The traditional process of PCCG preparation (LIPI, 2009) was modified by optimising the initial moisture content of the corn grits. The roughly milled grits were soaked in water at a ratio of 1:3 (w/v) for 2 d with water replacement after 24 h. Then, the grits were drained and milled using 2-speed grinder (Waring Products Inc., Connecticut, USA) into fine size (<300 μm). Subsequently, the fine grits were mixed with water to obtain 30%, 35%, 40%, and 45% of initial moisture content. The mixture was then formed into agglomerates, and steamed for 30 min at 100°C. Then, the steamed corn grits were dried using hot air at 70°C and 15 cm/s airflow rate until the final moisture content reached 8 ± 2%. The dried PCCG was stored in vacuum plastic bags until further analysis. The properties of PCCG prepared with the optimum condition using the traditional process were compared with the properties of PCCC prepared with optimum conditions using the improved process.

Development of improved PCCG preparation

Response surface methodology (RSM) was used as an optimisation technique in the improved process of PCCG preparation. The experimental design, the statistical analysis and the regression model were developed using the Minitab 16.0 software (Minitab Inc., State College, PA, USA). The Central composite design was used with three factors (corn particle size, initial moisture content, and processing temperature) and three levels (-1, 0, 1). Corn particle sizes used in the present work were 300, 850 and 1,400 μm which were obtained by milling the roughly milled corn using a blender (Waring blender 2-speed, Connecticut, USA). The grit particles were sieved using laboratory test sieve (Endecotts, Ltd, London, UK) until a certain fraction size of grits was obtained. Three initial moisture contents of PCCG were used namely 40%, 50% and 60%. The temperatures used for steaming were 115°C, 120.5°C and 126°C. The mixture was placed in a glass jar and tightly closed with a cap and was steamed for 5 min using an autoclave. Subsequently, the grits were dried using hot air at 70°C and 15 cm/s air flow rate until the moisture content reached 8 ± 2%. Then, the dried PCCG was stored in vacuum plastic bags until required for further analysis. The optimum conditions to prepare PCCG could be acquired using the response optimiser of RSM. The predicted values obtained under the suggested optimum conditions were then compared with the experimental values using a one-sample t-test to verify the validity of the model.

Analysis of physicochemical properties

The physicochemical properties of dried PCCG, namely water absorption index (WAI), water solubility index (WSI), yellowness index (YI), and resistant starch (RS), as well as the textural properties of rehydrated PCCG were evaluated as the response of processing parameters of PCCG prepared using the traditional and improved processes.

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

WAI and WSI were determined as described by Ding *et al.* (2005). Briefly, 3.0 g sample was weighed and mixed with 30 mL distilled water. The solution was stirred gently for 10 min at 200 rpm, and incubated in a water bath (WNB 14, Memmert GmbH + Co, Schwabach, Germany) for 30 min at 30 ± 2°C, and followed by centrifugation (EBA 20, Hettich Instrument, Massachusetts, US) at 3,000 rpm for 15 min. The pellet was collected into a crucible of known weight, dried at 105°C using hot air oven (Memmert UF110, Memmert GmbH + Co, Schwabach, Germany), and weighed until it reached a constant weight. The WAI was calculated as the weight of sediment/gel obtained after separating the supernatant (Equation 1). The WSI was calculated as the weight of dry solids in the supernatant expressed as a percentage of the original weight of the sample (Equation 2).

$$\text{WAI (g/g)} = \frac{\text{Weight gain by gel}}{\text{Dry weight of sample}} \quad (1)$$

$$\text{WSI (\%)} = \frac{\text{Weight of dry solids in supernatant}}{\text{Dry weight of sample}} \times 100\% \quad (2)$$

Yellowness index (YI)

YI of the dried PCCG surface was measured by a Hunter Lab JUKI colorimeter (JP7100P, Hunter Association Laboratory Inc., Reston, Virginia). The colorimeter was calibrated with a standard white plate before the measurement, with X = 12.28, Y = 12.34 and Z = 14.56. Illuminant D65 and 10° of standard observer function were used in the measurement. CIE tristimulus values represented the colour of dried PCCG. YI was calculated using ASTM Method E313 (Equation 3).

$$\text{YI E313} = \frac{100(C_x x - C_z z)}{Y}$$

where:

C_x (D65/10°)= 1.3013

C_z (D65/10°)= 1.1498

Resistant starch (RS)

RS was determined using a Megazyme assay kit (K-RSTAR 09/14) from Megazyme International Ireland (Cp. Wicklow, Ireland), which is an enzymatic assay following AOAC 2002.02 (AOAC International, 2011). RS was calculated as the amount of glucose × 0.9 (g/100 g).

Textural properties

A texture analyser TA-XT.plus (Stable Micro System Ltd., Surrey, UK) was used to determine the textural properties of rehydrated PCCG according to the modified method of Le and Jittanit (2015). Briefly, 10 g PCCG was added to 10 mL distilled water and heated in the microwave (National NN-C2000P, Matsushita Electric Industrial Co., Ltd., Osaka, Japan) for 1 min. A cylindrical plastic container with 60 mm in diameter was used to place the rehydrated PCCG. A cylindrical probe with 36 mm diameter was used to compress the rehydrated PCCG to 85% deformation of the original sample height. The speed settings used were a pre-test speed of 1 mm/s, a test speed of 5 mm/s, and a post-test speed of 10 mm/s. Hardness, adhesiveness, cohesiveness, chewiness, and resilience were determined.

Statistical analysis

All analyses were carried out in triplicate and the experimental values were reported as mean ± standard deviation. Statistical analyses were performed using Minitab 16.0 software (Minitab Inc., State College, PA, USA). Analysis of variance (ANOVA) with 95% confidence levels was performed for each response variable to analyse the significance among individual mean values.

Results and discussion

Traditional PCCG preparation with optimised initial moisture content

The initial moisture content for the preparation of traditional PCCG must be first determined to obtain the optimised value as no clear study has yet been conducted in this regard. This was done by preparing PCCG with four levels of the initial moisture content (30%, 35%, 40%, 45%) for the traditional process. The physicochemical properties of dried PCCG properties namely WAI, WSI, YI, and RS, as well as the textural properties of rehydrated PCCG prepared using the traditional process at varying initial moisture contents are presented in Table 1.

Table 1. Characteristics of PCCG under various initial moisture contents.

Characteristic	Initial moisture content (%)			
	30	35	40	45
WAI	3.15 ± 0.03[d]	3.45 ± 0.05[c]	3.96 ± 0.02[a]	3.58 ± 0.11[b]
WSI (%)	1.44 ± 0.08[b]	1.45 ± 0.05[b]	1.61 ± 0.06[a]	1.64 ± 0.05[a]
YI	79.86 ± 5.30[c]	88.84 ± 3.18[b]	95.78 ± 1.90[a]	96.71 ± 2.82[a]
RS (g/100 g)	1.78 ± 0.02[b]	1.83 ± 0.02[b]	1.96 ± 0.04[a]	1.92 ± 0.01[a]
Textural properties				
Hardness (Kg)	32.99 ± 0.46[a]	30.24 ± 0.16[b]	26.60 ± 0.28[c]	26.66 ± 0.54[c]
Adhesiveness (-g/s)	49.47 ± 0.48[a]	55.83 ± 1.24[b]	67.40 ± 0.83[c]	75.29 ± 1.99[d]
Cohesiveness	0.54 ± 0.01[b]	0.55 ± 0.02[b]	0.65 ± 0.00[a]	0.52 ± 0.00[d]
Chewiness (× 10^3)	13.91 ± 50[a]	13.69± 0.08[a]	11.59 ± 0.37[b]	10.48 ± 0.28[c]
Resilience	0.45 ± 0.01[b]	0.49 ± 0.02[a]	0.50 ± 0.00[a]	0.45 ± 0.01[b]

Data represent mean ± standard deviation. Mean values within rows sharing the same letter are not significantly different at p < 0.05. WAI: water absorption index, WSI: water solubility index, YI: yellowness index, RS: resistant starch.

WAI and WSI

Water absorption is associated with starch dispersion in excess water, which is affected by the degree of starch damage due to the gelatinisation process. The WAI indicates the volume occupied by the starch that swells and maintains its integrity in excess water (Yagci and Gogus, 2008). Water solubility is used as an indicator of molecular degradation of components, which indicates the degree of starch conversion during processing (Ding *et al.*, 2005). The initial moisture content of PCCG significantly affected ($p < 0.05$) the WAI and WSI values of PCCG. The WAI value of PCCG increased from 3.15 g/g dry sample to 3.96 g/g dry sample at 30%-40% initial moisture content but further decreased to 3.58 g/g dry sample at 45% initial moisture content (Table 1). Increasing the initial moisture content significantly increased the WAI value of PCCG, which was probably caused by the higher degree of gelatinisation. This result was consistent with earlier reports for rice, pea, and pearl millet (Singh, 2007; Al-Rabadi *et al.*, 2011; Yadav *et al.*, 2014). However, the decrease in the WAI value of PCCG at 45% initial moisture content might be due to excessive disruption of the starch granule structure during gelatinisation with a subsequent increase in the initial moisture content. A similar finding was previously reported by Jaiboon *et al.* (2011) in rice kernel. At a certain point during heating, starch reaches the maximum ability to absorb water. Continued heating in excessive water leads to further disruption of the starch and loss of its ability to hold water, thus leading to inability of the granule to maintain its integrity (Prasert and Suwannaporn, 2009). At the same time, the WSI values of PCCG were observed to increase from 1.45% to 1.64% as the initial moisture content increased (Table 1). During heating, starch components continue to leach out of the granules as the initial moisture content increases (Wang *et al.*, 2014).

YI

Colour is one of the important factors affecting consumers' preferences. The yellow colour of corn has been attributed to the presence of carotenoids, especially lutein and zeaxanthin (Khoo *et al.*, 2011). Yellow corn, which possesses nutritional benefits and phytochemicals such as phenolics, ferulic acid and flavonoids, can be considered as a functional food. Table 1 shows the YI value of PCCG as a function of the initial moisture content. The YI value of PCCG ranged from 79.86 to 96.65 at 30%-45% initial moisture content. The higher YI value of PCCG at a higher initial moisture content might correspond to a larger agglomerate particle produced during mixing. Higher initial moisture content made the fine grits sticking to each other, thereby producing the larger size of the particles. Due to the large size of the corn agglomerate particle, the inside part of the grits became less exposed. A comparable finding has been reported by Kim and Shin (2014) for rice cooked at different degrees of milling.

RS

RS is the starch fraction that cannot be digested in the small intestine but is fermented in the colon by beneficial microorganisms that produce short-chain fatty acids (Birt *et al.*, 2013; Raigond *et al.*, 2015). RS has several advantages such as to prevent hyperglycaemia-related diseases (Eliasson, 2010; Li *et al.*, 2016). Starch processing that involves gelatinisation and retrogradation results in the formation of RS3 (Li *et al.*, 2016). The RS values of PCCG generated with different initial moisture contents are presented in Table 1, which ranged from 1.78 to 1.96 g/100 g. Higher initial moisture content produced more RS. Starch granules are gradually and irreversibly disrupted during gelatinisation. The higher initial moisture content of PCCG was more effective in recrystallisation due to re-association of a significant amount of short linear D-glucose occurring with the presence of water as the plasticiser, which resulted in the generation of more RS (Sarangapani *et al.*, 2015). The production of more RS due to retrogradation also has a significant effect ($p < 0.05$) of increased water absorption as compared to granular starch. This result has been supported by the previous discussion about the effect of initial moisture content on the WAI value of PCCG. According to Chung *et al.* (2009) and Neslihan and Gocmen (2013), the combination of temperature and initial moisture content is well known to influence the gelatinisation degree, which has a direct relationship with RS content in starch. However, at 40% and 45% initial moisture content, there was no significant difference ($p \geq 0.05$) in RS content. This could be due to the fact that 40%-55% moisture content can be categorised as intermediate moisture content, in which RS would form more effectively due to the crystalline perfection of starch (Tester and Debon, 2000). This result is consistent with a previous report by Liu and Thompson (1998) regarding several types of waxy maize, although the specific relationship between initial moisture content and maximum retrogradation varied for different types of starch used.

Textural properties

Texture is the primary quality parameter of convenient carbohydrate based product, which is influenced by the gelatinisation process of corn (Brenda *et al.*, 2014). Table 1 demonstrates the effect of initial moisture content on the textural properties of PCCG. The hardness and chewiness of rehydrated PCCG decreased significantly ($p < 0.05$) as the initial moisture content increased. Higher initial moisture content during heat processing caused an increase in water diffusion into the corn grit granules. Consequently, it produced corn grits with a softer texture and less chewiness that required less energy to swallow. This result was similar to that of instant rice as reported by Prasert and Suwannaporn (2009). Daomukda *et al.* (2011) added that gelatinisation required an adequate amount of water. Therefore, increasing the ratio of water to rice tended to increase the gelatinisation degree of cooked rice. Moreover, adhesiveness increased as the initial moisture content increased. Leaching of starch components during the processing appears to be responsible for adhesiveness (Sarangapani *et al.*, 2015). Starch components continued to leach out of the granules as the initial moisture content increased, making the texture of rehydrated PCCG more adhesive (Wang *et al.*, 2014). In addition, the higher initial moisture content also resulted in higher cohesiveness and resilience. Nevertheless, the subsequent addition of water to reach more than 40% initial moisture content caused the texture of rehydrated PCCG to become too mushy that lost its cohesiveness and resilience. Regarding textural properties, it can be summarised that the different initial moisture contents of PCCG affected its rehydrated textural properties, and the optimum initial moisture content was found to be 40%.

Development of improved PCCG preparation
Optimisation process

RSM was utilised to model the physicochemical properties of PCCG with respect to the process variables. Independent and dependent variables were fitted with second order model equation and were checked for the goodness of fit. The model with a high R^2 value and no significant lack-of-fit was selected as the primary response. Table 2 shows the regression coefficients of the second order polynomial equations and the results of the full quadratic processing parameters on each response variable. YI, RS and resilience were used as the primary responses in RSM of PCCG processing, with their R^2 values being 0.92, 0.94 and 0.97, respectively. The final constructed models in terms of significant factors were as follows:

$$\text{YI} = 41.33x_1 + 1.58x_2 + 3.58x_3 - 0.19x_1 x_2 - 7.90x_1^2 - 0.02x_2^2 - 0.01x_3^2 \quad (4)$$

$$\text{RS} = -13.20x_1 - 0.07x_2 - 0.69x_3 - 0.01x_2 + 0.1x_1x_3 + (0.2 \times 10^{-2})x_2 x_3 + 0.51x_1^2 - (0.16 \times 10^{-2})x_2^2 \quad (5)$$

$$\text{Resilience} = 0.43x_1 + 0.03x_2 + (0.24 \times 10^{-2})x_3 - (0.51 x 10^{-2})\, x_1 x_2 + 0.08x_1^2 - (0.30 \times 10^{-3})\, x_2^2 \quad (6)$$

Optimisation was conducted using a response optimiser based on the desirability (multiple response method). Maximum YI (99.82), targeted RS (3.63 g/100 g) and maximum resilience (0.54) were chosen to obtain the predicted optimum condition of PCCG preparation. By applying 0.93 desirability, the optimum conditions to prepare PCCG were determined as 300 μm corn particle size, 52.33% initial moisture content, and 123.67°C processing temperature.

Table 2. Regression coefficients of the polynomial function and the coefficients of determination (R2) for the responses

Parameter	Coefficient	WAI	WSI	YI	RS	Texture Profile				
						Hardness	Adhesiveness	Cohesiveness	Chewiness	Resilience
Intercept	β_o	-	-	-	-	-	5,903.20**	-	-1,091,732*	-
Corn particle size (x_1)	β_1	0.34*	1.39*	41.33*	-13.20*	-26,876*	230.76*	-0.59 *	24,976*	0.43*
Initial moisture content (x_2)	β_2	0.11*	-0.12*	1.58*	-0.07*	2,636*	-2.85*	0.109*	4,102*	0.03*
Processing temperature (x_3)	β_3	-0.55*	0.50*	3.58*	-0.69 *	14,427*	-99.16*	0.14*	16,341*	0.24×10^{-2}*
x_1x_2	β_{12}	-	0.01*	-0.19*	-0.02*	-	-	-	-199**	-
x_1x_3	β_{13}	-	-0.02*	-	0.11*	-	-	-	-	-0.51×10^{-2}*
x_2x_3	β_{23}	-	0.01*	-	0.20×10^{-2}*	-	-	-0.6×10^{-3}*	-26*	-
x_1^2	β_{11}	0.32*	0.55*	-7.90*	0.51*	-	-	-	-	0.08*
x_2^2	β_{22}	-	-	-0.02*	-0.16×10^{-2}*	-	0.02 **	-0.4×10^{-3}*	-	-0.30×10^{-3}**
x_3^2	β_{33}	-	-	0.01*	-	-	-	-	-62**	-
	R^2	0.91	0.96	0.92	0.94	0.90	0.84	0.96	0.93	0.97
	Sig Lack-of-fit	0.00	0.70	0.00	0.00	0.00	0.00	0.16	0.07	0.00

*indicates that the value is significant at $p < 0.05$, ** indicates that the value is significant at $p < 0.1$

WAI: water absorption index, WSI: water solubility index, YI: yellowness index, RS: resistant starch

Table 3. Predicted and experimental values for the response variables.

Response variables	Optimum processing parameters			Optimum values	
	Corn particle size (µm)	Initial moisture content (%)	Processing temperature (°C)	Predicted	Experimental
YI	300	52.33 %	123.67	99.82[a]	99.08 ± 1.23[a]
RS (g/100 g)	300	52.33 %	123.67	3.63[a]	3.65 ± 0.08[a]
Resilience	300	52.33 %	123.67	0.54[a]	0.53 ± 0.02[a]

Data represent mean ± standard deviation. Mean values within rows sharing the same letter are not significantly different at $p < 0.05$. YI: yellowness index, RS: resistant starch.

Validation

The optimum conditions for PCCG preparation process were validated by comparing the response variable based on the predicted and the experimental response values using one sample *t*-test. Table 3 shows the predicted and experimental values of PCCG preparation based on the RSM responses. Using 95% confidence levels, the experimental values of the response were found to be not statistically different from the predicted ones, which indicated that the model was in a good agreement with the experimental response values. Furthermore, the optimum processing conditions showed a shorter preparation time of PCCG of approximately 4-6 h.

Comparison between PCCG prepared using the traditional and improved processes

Based on the values of WAI, YI, and RS of dried PCCG, as well as the textural properties of rehydrated PCCG, it could be concluded that the optimum initial moisture content to prepare PCCG by the traditional process was 40%. Subsequently, the PCCG prepared under this condition was compared with the PCCG prepared using the improved process using 300 µm corn particle size, 52.33% initial moisture content, and 123.67°C processing temperature. The physical appearance of PCCG prepared by the traditional process and that of PCCG prepared using the improved process are shown in Figure 1. The PCCG particle size prepared using the improved process was smaller and more homogenous than that prepared using the traditional process. This is because the sieving process produced grits of consistent and more homogenous size, which consequently prevented agglomeration of the particle during the mixing of corn grits and water. The values of physicochemical properties (WAI, WSI, YI, RS) of dried PCCG along with the textural properties of rehydrated PCCG prepared using the traditional and the improved processes are shown in Table 4. Most of the textural parameters showed no significant difference ($p \geq 0.05$) between the traditional and the improved processes namely hardness, chewiness and resilience. However, WAI, WSI, YI, RS, adhesiveness, and cohesiveness exhibited a significant difference ($p < 0.05$) between the two processes of PCCG

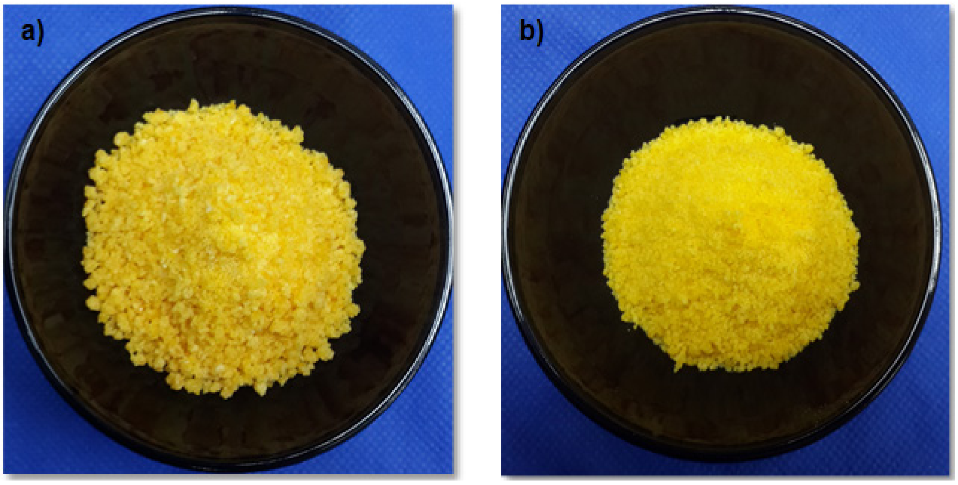

Figure 1. Physical appearance of PCCG a) prepared by the traditional process, b) prepared by the improved process.

Table 4. The properties of PCCG prepared by traditional and improved processes

Response variables	Traditional	Improved
WAI	3.99 ± 0.02[a]	3.74 ± 0.12[b]
WSI (%)	1.61 ± 3.96[b]	1.68 ± 0.04[a]
YI	96.54 ± 0.02[b]	99.51 ± 0.21[a]
RS (g/100 g)	1.96 ± 0.04[b]	3.65 ± 0.08[a]
Textural properties		
Hardness (kg)	26.60 ± 0.28[a]	26.79 ± 0.16[a]
Adhesiveness (-g.s)	67.40 ± 0.83[b]	102.24 ± 3.53[a]
Cohesiveness	0.65 ± 0.00[b]	0.66 ± 0.01[a]
Chewiness (× 10^3)	11.59 ± 0.37[a]	11.36 ± 0.35[a]
Resilience	0.50 ± 0.00[a]	0.53 ± 0.03[a]

Data represent mean ± standard deviation. Mean values within rows sharing the same letter are not significantly different at $p < 0.05$. WAI: water absorption index, WSI: water solubility index, YI: yellowness index, RS: resistant starch.

preparation. Nevertheless, it must be noted that PCCG prepared using the improved process did not produce undesirable flavour of the final product due to the short time of preparation (4-6 h) when compared with the traditional process that involved soaking for two days. Several studies of corn product preparation (*atole, kenkey, tuwo*, and *ogi*) which involves soaking for several days in regions of South and West Africa reported undesirable odour of the final product due to bacterial activity in the soaked water (Halm *et al.*, 2004; Sangwan *et al.*, 2014).

The WAI value of PCCG prepared using the improved process was significantly lower than that of PCCG prepared using the traditional process. According to Liu *et al.* (2009), the high temperature treatment resulted in lower water absorption of the starch granule as an intact granular structure was maintained. In contrast, the WSI value of PCCG prepared using the improved process was higher than that of PCCG prepared using the traditional process. As reported by Tan *et al.* (2009), the WSI value of starch increases as the temperature rises, which resulted in the increase of leached starch. YI and RS of PCCG prepared by the improved process were significantly higher ($p < 0.05$) than those of PCCG prepared using the traditional process (Table 4). This finding is similar to rice parboiling reported by Odjo *et al.* (2012). Colour change during heat processing in the improved process was significantly influenced by temperature, which markedly increased the colour intensity and yellowness. The RS of PCCG prepared by the improved process was almost double the value (3.65 g/100 g). Although the initial moisture content used in both the traditional and the improved processes was categorised as intermediate moisture content (40%-55%) that could result in a more effective RS formation, Dundar and Gocmen (2013) reported that a higher processing temperature was more effective in RS formation in corn starch due to the increase in crystalline perfection in corn. The higher RS value of PCCG prepared by the improved process could be preferred due to the nutritional advantage. RS in the diet has a laxative effect, preventing colorectal cancer, reducing blood glucose, and also regulating metabolic and inflammatory intestinal diseases (Perera *et al.*, 2010; Raigond *et al.*, 2015; Hung *et al.*, 2016). According to Sirisoontaralak *et al.* (2015), the daily intake of RS in the United States is approximately 4.9 g/day. A single serving of PCCG produced by the improved method contributed to 4.75 g/ 130 g PCCG, which implies that it could fulfil 96.94% of RS daily intake. This value is higher than the consumption at the same amount of instant germinated brown rice that contributes only 0.96 g per serving. The improved method proposed in the present work may offer the possibility to produce PCCG with a higher RS content in a shorter time of preparation in the household.

Adhesiveness and cohesiveness of PCCG prepared by the improved process were found to be higher than those of PCCG prepared by the traditional process. Adhesiveness of rehydrated PCCG prepared by the traditional process was significantly lower ($p < 0.05$) than that of PCCG prepared using the improved process. This was due to the larger particle size of PCCG prepared by the traditional process. According to Kim and Shin (2014), cohesiveness of cupcake prepared using larger size rice flour was lower than that of other cupcakes prepared using smaller size rice flour. Moreover, a coated film of leaked amylose could form three-dimensional networks on the surface of corn grits, thereby giving rise to a higher cohesive value of PCCG (Leelayuthsoontorn and Thipayarat, 2006; Tian *et al.*, 2014).

Conclusion

The optimum initial moisture content to prepare PCCG by the traditional process was 40%. The initial moisture content in the traditional PCCG preparation process had a significant ($p < 0.05$) effect on WAI, YI, and RS of dried PCCG as well as on the textural profile of rehydrated PCCG. The optimum conditions to prepare PCCG by the improved process were determined as 300 µm corn particle size, 52.33% initial moisture content and 123.67°C processing temperature. PCCG prepared using the improved process showed a significantly higher value of YI (99.51) and RS (3.65 g/100 g), but significantly lower of WAI value (3.74) than those of PCCG prepared by the traditional process. Furthermore, the textural properties of rehydrated PCCG, except for cohesiveness and adhesiveness, prepared using the improved process were not significantly different ($p \geq 0.05$) from those of PCCG prepared using the traditional process. The improved process of PCCG preparation required a shorter time of 4-6 h. Thus, this improved process could provide a choice to produce convenience PCCG for outdoor use or food supplies during disasters.

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