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Optimization of glutinous rice crackers incorporated with green banana (*Musa sapientum* L.) flour and cricket *(Acheta domesticus)* powder

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Abstract

Due to the trend of functional food, essential nutrients were added to various kinds of food to enhance nutritional value. Considering alternative and sustainable sources of those nutrients is a challenging issue in food innovation. In this study, green banana flour (GBF) and cricket powder (CP) were used as sources of dietary fiber and protein, respectively, to improve nutritional quality in glutinous rice crackers. Therefore, this research aims to investigate the effects of formulation on the quality of rice crackers. Mixture design was used to formulate the glutinous rice crackers. The components consist of glutinous rice flour (GRF), GBF, and CP which were set at 50-100, 0-35, and 0-15%, respectively. Response surface methodology was used to optimize the appropriate levels of ingredients and examine the effects on the physical, chemical, and sensory properties of glutinous rice crackers. It was observed that higher GBF and CP contents increased hardness and bulk density which led to a decrease in expansion ratio and overall liking score. The optimum area was discovered by overlaying contour plots for the criteria responses and applying ingredient levels that set up limits of acceptable quality for each factor. The optimal point suggested 78.87% GRF, 16.07% GBF and 5.06% CP which will produce a rice cracker with good textural properties (2.15 expansion ratio, 0.29 g/cm^3 bulk density, and 997.70 g maximum force), nutritional value (6.83% protein and 4.10% total dietary fiber), and consumer acceptance (6.14 overall-liking score).

Keywords: Alternative protein, Dietary fiber, Crispy rice cracker, Healthy Snack

1. Introduction

Snacks are a worldwide popular meal for all consumers showing constant market growth. Thailand's snack market has grown unceasingly from 2013 until 2018, and is expected to grow dramatically from 2018 to 2023 (Renaud, 2019). A crisp rice cracker (Khao-Kreab-Wow) is an indigenous rice cracker produced from glutinous rice (*Oryza sativa*) or flour [1]. Khao-Kreab-Wow or Khao-Pong has a crispy texture, high fracturability, and high energy. However, the increased consumption of energy-dense food i.e., a high level of fat, sugar, and refined carbohydrates, as well as the reduction of physical activity, has been a cause of the obesity epidemic [2]. It was reported that 65% of adults looked for food and beverages that added vitamins and minerals, while others want 63% and 60% more fiber and protein, respectively [3].

Bananas and insects have been eaten for centuries all over Asia and other regions of the world. Green bananas are used as functional ingredients in food formulation due to their nutritional value such as a good source of resistant starch (RS), dietary fiber, as well as bioactive compounds such as phenolic acid which promote health benefits in humans [4]. RS is a faction of starch that is not digested in the small intestine and therefore becomes a substrate for the intestinal microbiota to produce short-chain fatty acids that promote health benefits and reduce risk factors for diet-related diseases. [5,6]. Recently, insects have become an emerging alternative to high-quality protein sources as well as micronutrients. Furthermore, it was claimed that insect farming is environmentally friendly compared to livestock due to its short life cycle in production [7]. Moreover, edible insects have a faster growth rate, a higher feed-into-food conversion efficiency, lower requirements for land and water, as well as lower emissions of greenhouse gas and ammonia compared to pigs and cattle [8]. Nowadays, there are many food innovations, including ongoing research and development. Towards the application of insects in food, insect-based food can be a protein source to enhance nutritional values found in a wide range of products such as cereals-based food, for example, adding cricket powder in bread [9], cereal bars [10], extruded snacks [11] porridge powder [12] and dietary supplement [13]. This research aimed to optimize the suitable levels of glutinous rice flour (GRF), green banana flour (GBF), and cricket powder (CP) and examine the effects on expansion, textural properties, sensory properties, and nutritional properties of glutinous rice crackers. The relationship between the pasting properties of mixed flour and the textural properties of rice crackers was also investigated.

2. Material and methods

2.1 Glutinous rice, green banana flour, and cricket powder

Thanyasirin glutinous rice (*Oryza sativa* L.) was obtained from the rice research center, Faculty of Agriculture, Khon Kaen University. The polished glutinous rice grains were pulverized using an ultra-centrifugal mill (ZM 200, SPRT Co., Ltd, Germany). The flour was sieved through a 60-mesh screen. The flour was vacuum-packed in a plastic bag and stored at room temperature until needed within a month.

Mature green Pak Chong 50 (PC50) banana (*Musa sapientum* L.) flour was received from a local supplier (Banana Mill company, Thailand) and kept at 5°C for around a month before use.

Adult crickets *(Acheta domesticus)* were supplied by Nay-Petchr Farm (Khon Kaen, Thailand), Fresh crickets were washed and boiled at 100°C for 5 mins to inhibit the enzymes and reduce the initial microbial load, then dried in the hot air oven at 60°C to obtain moisture -point of approximately 5%. The dried cricket was ground using a multi-purpose grinder (model MXG-SM500, Sumo Manufacturing, China) and sieved through a 20-mesh screen. The powder was vacuum packed and kept frozen at -20°C until use within a month.

2.2 Chemical composition analysis

The approximate composition of GRF, GBF, and CP and rice crackers were analyzed according to AOAC methods (AOAC, 2000). Crude proteins of GRF, GBF, and CP were analyzed using the Kjeldahl method by N*5.95, 6.25, and 5.09, respectively. Carbohydrates were determined by subtraction [100% - (%protein + %fat + %ash)]. Total dietary fiber (TDF), soluble dietary fiber (SDF), and insoluble dietary fiber were analyzed by enzymatic-gravimetric method [14].

2.3 Experimental Design

The 3 main compositions of GRF of 50-100%, GBF of 0-35%, and CP of 0-15% were optimized to formulate a mixed composite flour for the rice cracker using a D-optimal mixture design. The design contained 10 points with 3 replicated points (a replication of 3 treatments).

2.4 Pasting properties

The pasting properties of each single flour (GRF and GBF) and mixed flour (Table 1) were investigated using Rapid Visco^{TM} Analyzer (RVA-4, Newport Scientific, Australia). 2.5g of flour and the mixed flour were mixed with 25ml of distilled water. The initial temperature of testing was set at 50°C and the test was executed using the following steps. The test started at 50°C. The testing temperature was increased at a constant rate of 0.2°C/s to obtain 95°C. The temperature was held at 95°C for 3.5 min and cooled down at a constant rate of 0.18°C/s to 50°C. The pasting properties including pasting temperature, peak viscosity, breakdown, and setback were evaluated [15].

2.5 *Rice crackers preparation*

The formulation of rice crackers, added with GBF and CP, is shown in Table 1. The mixtures were mixed with water to obtain a moisture content of 55% and kneaded to form the dough. The rice dough was steamed for 30 min then immediately kneaded for 10 min (speed level 2) by an electric dough mixer (model 800-B, Spar Food Machinery MFG. Co., LTD., Taiwan) with a hook. Sugar of 10:3 ratio (Flour: Sugar) was mixed during kneading. The rice dough was rolled into a sheet of approximately 1 mm thickness, molded into a circle shape using a metal hollow cylinder of 4 cm diameter, then dried in a hot air oven (model 12-Tray, KluayNamThaiTowop, Thailand) at 55°C for 3hr to obtain a moisture content approximately 11±1% to produce a dried dough plate. The dried plates were baked in an electric baking oven (model ST-92, Salva, Spain) at 180°C for 6 min. The rice crackers were cooled at room temperature, then consequently packed in an LLDPE plastic bag and stored at room temperature for further analysis.

Table 1 Mixture's composition of glutinous rice cracker formulated with GBF and CP.

Formula	Composition (%)		
	GRF	GBF	CP
F1	70.75	29.25	0
F2	75.00	17.50	7.50
F3	92.18	1.58	6.24
F4	70.75	29.25	0
F5	86.00	0	14.00
F6	75.00	17.50	7.50
F7	89.38	10.13	0.49
F8	100.00	0	0
F9	80.93	12.55	6.53
F10	56.12	35.00	8.88
F11	56.12	35.00	8.88
F12	75.15	9.85	15.00
F13	61.66	23.34	15.00

Note: F4, F6, and F11 were the replicated design points of F1, F2 and F10, respectively.
Source: Design Expert trail software version 12.0 (State-Ease, USA)

2.6 Rice cracker qualities

2.6.1 Color (Consider whiteness index)

The color of the crackers was determined by the CIE color system (L*, a*, and b*) using a Hunter Lab spectrophotometer (Ultra Scan XE, Hunter Lab, USA).

2.6.2 Textural properties of rice cracker

The crackers were determined for texture using Texture Analyzer (Model: TA.XT *plus*, Stable Micro System Co.Ltd., UK) following [16]. The load cell and height were calibrated at 5 kg and 10 mm, respectively. The pre-test, test, and post-test speed was set up at the same speed of 10 mm/s. Each sample was placed on a sample holder (an aluminum plate with a hole) to allow the probe to pass through. The cylinder probe (P/2S) was penetrated through the 15 pieces of crackers at room temperature. The maximum force and number of count peaks (Threshold = 50 g) were reported as hardness and crispness of the cracker, respectively.

2.6.3 Bulk density

The bulk density of rice crackers was determined using the seed displacement method [17]. Sesame seeds were filled in a volumetric container (250 ml beaker), then replaced with some sesame seeds with a known weight (g) of 3 pieces of rice cracker sample. The difference in sesame volume with and without the samples was defined as the cracker volume (cm^3). Bulk density was calculated according to the following equation (1). Each treatment was performed with at least 5 determinations.

$$\text{Bulk density}\left(\frac{g}{cm^3}\right) = \frac{\text{Weight of sample (g)}}{\text{Volume of sample }(cm^3)} \quad (1)$$

2.6.4 Expansion ratio

The expansion ratio is a parameter used to determine a volume change regardless of the shape using equation (2). The dried dough plate before baking and the cracker after baking were determined for a bulk volume using the seed displacement method.

$$\text{Expansion ratio} = \frac{\text{Volume after expansion}}{\text{Volume before expansion}} \quad (2)$$

2.6.5 Sensory evaluation

The acceptance test of the rice crackers product was performed by 50 untrained panelists in the individual sensory booth. The protocols for sensory evaluation were informed to the panelists before the evaluation. The panelists were asked to taste the products and evaluate the sensory properties as well as the acceptability using a 9-point scale hedonic test. Three pieces of the sample were served in a low-density polyethylene (LDPE) plastic bag. The bags were labeled with random three-digit codes. According to the balance and carry-over effects design [18], the order of the representation samples was randomly served. The panelists were asked to rinse their mouths with drinking water between each sample.

2.7 Statistical analysis

A completely randomized design (CRD) was performed for chemical and physical analysis. Sensory evaluation was conducted under a Randomized Complete Block Design (RCBD). Analysis of variance was performed by ANOVA. Significant differences between means are determined using Duncan's multiple range test ($p < 0.05$). Statistical analysis was carried out using SPSS version 23.0 (IBM Inc, USA).

Response surface methodology (RSM) was used for optimization. The independent variables are established as parameters based on the levels of ingredients using GRF, GBF, and CP. The mathematical model for each parameter was obtained by response surface plots generated by using the Design Expert Version 12 trial Software (Stat-Ease, USA). The data were analyzed for variance (ANOVA) to verify the quality of fit of the experimental model using the coefficient of determination (R^2). The linear, quadratic, and cubic models were used to represent the fitted response values. The suitable models to be selected for optimization should be significant ($p < 0.05$), high coefficient of determination ($R^2 > 0.70$), and non-significant lack of fit ($p > 0.05$).

3. Results and discussion

3.1 Proximate chemical compositions of GRF, GBF, and CP

GRF, GBF, and CP had their chemical compositions and moisture content analyzed, the results are in Table 2. Glutinous rice flour presents the highest moisture content of 11.19%, followed by GBF 8.30% and Cricket powder 6.03%. Carbohydrates made up the largest portions in GRF and GBF by 88.57 and 89.01% respectively. Whereas cricket powder was only 10.68% carbohydrate.

Table 2 Proximate chemical compositions of GRF, GBF, and CP.

Composition (g/100g db)	GRF	GBF	CP
Moisture	11.19±0.15^a	8.30±0.16^b	6.03±0.08^c
Carbohydrate	88.57±0.19^a	89.01±0.03^a	10.68±0.39^b
Protein	8.01±0.01^b	3.84±0.02^c	55.83±0.06^a
Fat	1.07±0.02^c	1.53±0.01^b	14.89±0.29^a
Ash	0.35±0.01^c	2.80±0.01^b	4.72±0.05^a
TDF	3.53±0.48^c	10.70±0.15^a	8.17±0.33^b
- SDF	1.23±0.02^b	0.87±0.13^c	1.72±0.14^a
- IDF	2.31±0.49^c	9.84±0.03^a	6.45±0.47^b

TDF: Total dietary fiber, SDF: Soluble dietary fiber, IDF: Insoluble dietary fiber
Value with different letters in the same row is significantly different ($p < 0.05$).

Protein contents in GRF, GBF, and CP were 8.01, 3.84, and 55.83% respectively. CP was remarkably higher in protein content compared to GRF and GBF. The result agreed with Moongngarm [19] and Eakkanaluksamee & Anuntagool [20] who reported that protein content in a famous Thai glutinous rice of RD6 variety, was in the range of 6-8%, Moreover, protein in green banana flour (Musa ABB group) was found by Moongngarm [19] in the percentage of 4.01. However, protein contents of CP were reported in wide ranges, depending on various varieties and the conversion factors used for the quantitative calculation. With a conversion factor of 4.76, protein contents of CP had been reported in the range of 42.0-45.0 % in *Acheta domesticus* [21]. Protein content in two cricket species, *Acheta domesticus,* and *Gryllus bimaculatus* were 60.7, and 71.7%, respectively [22] (conversion factor of 6.25).

Fat contents in GRF, GBF, and CP were 1.07, 1.53, and 14.89% respectively. CP shows the highest fat content compared to GRF and GBF. The result was close to Moongngarm [19] reported that the lipid in RD6 waxy rice was 1.85%. 0.98% fat in green Namwa banana was found by Vatanasuchart et al. [23]. Furthermore, fat content in CP (*Acheta domesticus*) was reported in the large range of 10.40-27.08% [23,24].

CP had the highest ash content (4.72%), while GRF had the lowest (0.35%). Ash in GBF was 2.80%. The result was close to a study by Udomsil et al. [22] who reported ash in *Acheta domesticus* in the percentage of 5.4. Ash content in GBF in this study was on the same line as Vatanasuchart et al. [23] that the ash of three varieties of Kluai Namwa was in the range of 2.32-3.07%.

GBF had the highest and GRF had the lowest content of total dietary fiber. Total dietary fiber of GRF, GBF, and CP were 3.53, 10.70, and 8.17 %, respectively. The insoluble dietary fiber was the majority in all samples. The result was close to Vatanasuchart et al. [23] reported the amount of total dietary fiber in three varieties of Kluai Namwa in the range of 10.39-12.70 %.

3.2 Pasting properties of GRF and GBF.

The pasting properties of GRF and GBF are shown in Table 3. GRF exhibited significantly higher peak viscosity and breakdown while lower final viscosity, setback, and pasting temperature than those of GBF ($p < 0.05$). The high pasting temperature while low final and setback viscosity may be caused by amylose content rather than amylopectin. Thus, it indicated that GBF contained higher amylose content leading to more retrogradation compared to GRF. GBF presented a smaller number of breakdown compared to GRF which exhibiteds lower paste stability.

The results were closed and agreed with Nimsung et al. [25] that viscosity at peak, final, breakdown, setback, and pasting temperature of green banana flour (Kluai Namwa) were 212, 230, 43.5, 61.8 RVU, and 77.6°C, respectively. Pongjanta et al. [26] reported peak, hold strength, breakdown, final viscosity, setback, and pasting temperature at 263.19, 144.97, 118, 941.33, -78.44 RVU, and 65.98°C, respectively.

Table 3 Pasting properties of GRF and GBF.

Flour	Pasting Viscosity (RVU)					Pasting
	Peak	Hold	Final	Breakdown	Setback	Temp (°C)
GRF	251.08±1.73^a	104.19±0.75^b	129.50±2.73^b	146.89±2.23^a	25.30±3.02^b	70.40±0.05^b
GBF	164.80±24.18^b	149.08±22.12^a	210.50±31.26^a	15.72±2.10^b	61.41±9.21^a	83.92±0.46^a

Value with different letters in the same column is significantly different ($p < 0.05$).

3.3 Pasting properties mixed flours among GRF, GBF, and CP

It is important to understand the pasting behavior of flour, which is related to the texture and structure of food products, especially starch-based food [27]. Table 4 shows the pasting profiles of the mixed flour of GRF, GBF, and CP. The pasting properties of the mixed flour were significantly influenced by GRF, GBF, and CP ($p < 0.05$). Quadratic mathematic models were fitted to peak viscosity, hold viscosity, breakdown viscosity, and final viscosity with the significance of $p < 0.0001$, $p = 0.0437$, $p < 0.0001$, $p = 0.0307$, respectively. While the linear model of $p < 0.0001$ and $p = 0.0001$ were fitted to set back viscosity and pasting temperature, respectively.

The peak viscosity of the mixed flours, which ranged from 79.92 to 245.83 RVU, decreased as the GBF and CP increased. In contrast, the pasting temperature rose from 69.32 to 76.15°C with the increase of GBF and CP, reflecting the change in swelling tolerance of starch granules. The increase in pasting temperature as the GBF and CP increased may be due to the formation of starch-lipid complexes which led to reduced swelling power and solubility of starch retards starch gelatinization and retrogradation. Moreover, it was worth noting that starch–lipid complexes formed an insoluble film on the starch granule surface, which delayed the absorption of water into starch granules and resulted in an increase in the gelatinization temperature [28]. The highest breakdown viscosity was found in the formula with the greatest amount of GRF (F8) while the lowest breakdown was found in the mixture with the highest GBF (F10 and F11). This figure shows that breakdown viscosity of mixed flour was significantly influenced by GBF rather than CP. This indicates that increasing GBF in the formula could reduce the paste stability of dough.

Setback, indicating the starch tendency of retrogradation, decreased with an increase in CP content. This might be because of the amylose-lipid complex formation of starch, resulting in a decrease in final viscosity [27]. Similar results were reported that the decrease of final viscosity and setback viscosity related to the additional level of fat and oil in the wheat dough [29].

Table 4 Pasting properties of mixed flours.

	Flour composition (%)			Viscosity (RVU)					Pasting Temperature (°C)
	GRF	GBF	CP	Peak	Hold	Breakdown	Final	Setback	
1	70.75	29.25	0	101.22 ± 4.30^{hi}	86.08 ± 4.05^{de}	15.14 ± 1.09^{g}	108.44 ± 4.92^{cd}	22.36 ± 1.07^{b}	71.67 ± 0.89^{cde}
2	75.00	17.50	7.50	109.72 ± 4.44^{g}	84.89 ± 3.17^{def}	24.83 ± 1.30^{f}	105.08 ± 3.26^{de}	20.20 ± 0.29^{c}	71.98 ± 1.37^{cd}
3	92.18	1.58	6.24	205.69 ± 1.64^{b}	94.42 ± 1.74^{b}	111.28 ± 3.36^{b}	118.83 ± 2.30^{b}	24.42 ± 0.80^{a}	70.12 ± 0.85^{de}
4	70.75	29.25	0	97.94 ± 3.10^{i}	83.78 ± 3.37^{ef}	14.17 ± 0.44^{g}	105.22 ± 2.91^{de}	21.44 ± 0.86^{b}	72.22 ± 1.21^{cd}
5	86.00	0	14.00	189.42 ± 4.13^{c}	91.89 ± 1.13^{bc}	97.53 ± 3.93^{c}	110.53 ± 1.19^{c}	18.64 ± 0.13^{d}	71.40 ± 0.87^{cde}
6	75.00	17.50	7.50	104.53 ± 3.80^{h}	81.36 ± 3.23^{fg}	23.17 ± 1.09^{f}	100.25 ± 3.32^{f}	18.89 ± 0.55^{d}	72.27 ± 0.38^{cd}
7	89.38	10.13	0.49	149.58 ± 4.88^{d}	88.33 ± 2.02^{cd}	61.25 ± 3.00^{d}	110.53 ± 1.60^{c}	22.19 ± 0.49^{b}	69.32 ± 3.85^{e}
8	100.00	0	0	245.83 ± 2.93^{a}	104.44 ± 2.23^{a}	141.39 ± 1.83^{a}	129.56 ± 2.55^{a}	25.11 ± 0.51^{a}	70.40 ± 0.05^{de}
9	80.92	12.55	6.53	122.28 ± 1.01^{e}	82.22 ± 0.96^{efg}	40.05 ± 0.21^{e}	102.50 ± 1.18^{ef}	20.28 ± 0.31^{c}	72.20 ± 0.48^{cd}
10	56.12	35.00	8.88	79.92 ± 0.98^{jk}	73.17 ± 1.42^{i}	6.75 ± 1.04^{i}	91.86 ± 1.62^{g}	18.69 ± 0.38^{d}	$75.08\pm0.85d^{a}$
11	56.12	35.00	8.88	83.94 ± 0.84^{j}	76.86 ± 0.38^{hi}	7.08 ± 0.72^{i}	95.47 ± 0.35^{g}	18.61 ± 0.43^{d}	76.15 ± 0.91^{a}
12	75.15	9.85	15.00	115.75 ± 1.51^{f}	78.80 ± 0.89^{gh}	36.94 ± 0.63^{e}	96.08 ± 0.96^{g}	17.28 ± 0.13^{e}	72.45 ± 0.39^{cd}
13	61.66	23.34	15.00	77.19 ± 0.17^{k}	66.70 ± 0.29^{j}	10.50 ± 0.37^{h}	83.61 ± 0.27^{h}	16.92 ± 0.17^{e}	73.57 ± 0.85^{bc}

Note: F4, F6, and F11 were the replicated design points of F1, F2 and F10, respectively.
RVU: Rapid Visco Unit. Value with different letters in the same column is significantly different ($p < 0.05$).

3.4 Physical properties of rice crackers added with GBF and CP

3.4.1 Color

The color parameters of glutinous rice crackers were significantly influenced by the composition of mixed flour ($p < 0.05$). A linear mathematical model as a function of GRF, GBF, and CP had a non-significant lack of fit and could explain lightness with R^2=0.9213. Special cubic models with a non-significant lack of fit were used to explain a* and b* with R^2=0.9473 and 0.9338, respectively ($p < 0.05$).

Lightness (L*) of the cracker was in a range from 41.19 to 57.51. The higher the GRF, the greater L* was observed. Additions of GBF and CP resulted in lower L* values (darker color, Figure 1). The deduction of lightness could be due to the brownish of GBF and CP and Maillard reaction that occurred during baking. The redness (a*) of the cracker was increased from 9.31 to 14.15. The a* value depended on GBF, as it was significantly higher with an increase in GBF. The additions of GRF and CP led to increases in yellowness (*b) of rice crackers that ranged from 19.38 to 27.71. The result was agreed with Da Rosa Machado & Thys [9] who found the lightness (L*) of bread decreased as the CP increased from 10 to 20%. Moreover, the a* and b* values were also increased once20% more CP was added compared to control (F8).

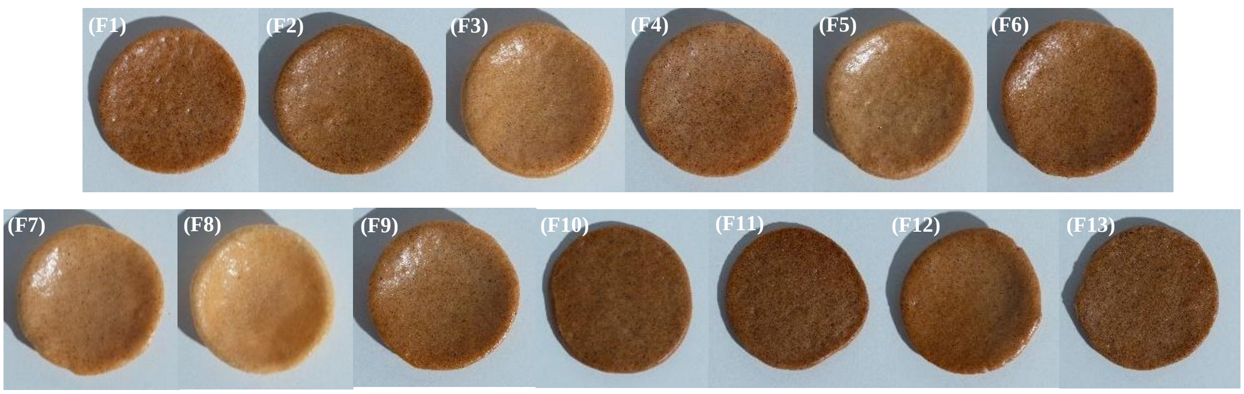


Figure 1 Glutinous rice crackers formulated with GBF and CP (%GRF-%GBF-%CP); F1&F4 (70.75-29.25-0.00), F2&F6 (75.00-17.50-7.50), F3 (92.18-1.58-6.24), F5 (86.00-0.00-14.00), F7 (89.38-10.13-0.49), F8 (100.00-0.00-0.00), F9(80.93-12.55-6.53), F10&11(56.12-35.00-8.88), F12 (75.15-9.85-15.00), F13 (61.66-23.34-15.00).

3.4.2 Expansion, bulk density, and textural properties

Expansion ratio, bulk density and the parameters related to textural properties, such as maximum force and the number of peaks were determined and shown in Table 5. The formula with a higher level of GRF (F3, F7, F8) resulted in lower hardness and bulk density but a higher expansion ratio. The maximum force (g) indicated the hardness of the crackers, ranging from 521.47 to 1370.55 g. As the percentage of GBF and CP increased, the maximum force and bulk density increased while the expansion ratio decreased. This tendency was also reported by Amini Khoozani et al. [30]. It was figured out that the use of whole green banana flour (WGBF) resulted in a denser, harder, and chewier bread with an increase in the substitution level WGBF ranged from 10-30%. Moreover, Da Rosa Machado & Thys [9] also reported an increase in the hardness of bread when comparing 20% additional CP to 10% CP and control. The decrease in expansion ratio as an effect of GBF and CP may be related to the water-holding capacity of the dried dough before baking which interrupted the water vaporization during baking. This result was consistent with the moisture content in the cracker which remained in greater amounts in the cracker with the higher GBF (Table 5).

3.5 Chemical properties

The chemical properties of glutinous rice crackers, including moisture content, protein content and dietary fiber, were determined and presented in Table 6. Moisture content tended to increase as the percentage of GBF increased. The protein contents of the cracker ranged from 4.17 to 11.39%. It was significantly influenced by the ingredients, especially cricket powder. The higher protein content resulted from the increase in CP, this was due to the high protein content of CP in the formulation. Additions of GBF and CP led to improvement of total dietary fiber (TDF) and insoluble dietary fiber (IDF) contents in the rice cracker ($p < 0.05$), except soluble dietary fiber (SDF) which is not significant ($p > 0.05$). TDF and IDF of rice cracker formula valued from 2.07 to 6.11 g/100 g and 1.36 to 5.01 g/100 g, respectively while SDF ranged from 0.61 to 1.35 g/100 g. The range of protein content of rice crackers in this research was similar to the study [9]. The protein content was found in the range of 8.53 to 12.52% when CP was added from 10 to 20%, respectively.

3.6 Effect of composition on sensorial properties of glutinous rice cracker

Sensory attributes of rice crackers were evaluated using hedonic scores as presented in Table 7. The results showed that GBF and CP contents influenced the acceptability ($p < 0.05$). Generally, the increment of GBF and CP as well as the reduction of GRF resulted in decreasing of the liking scores for all sensory attributes. Overall liking scores ranged from 4.34 (dislike slightly) to 7.66 (like moderately). Sensory evaluation of appearance, color, odor, taste, hardness and overall liking were explained by linear models. Nonetheless, a quadratic model was used to explain the crispness liking score.

The overall liking score dropped to 5.86 (neither like nor dislike) as the reduction GRF dropped to 70.75% in the mixture. However, the overall liking scores greater than 6.00 were found in the formulation with GRF from 80.93 to 100%. Appearance and color liking scores for glutinous rice crackers ranged from 4.64 to 7.64 and 4.26 to 7.60, respectively. Likewise, the liking score for appearance and color of the rice cracker decreased as GBF and CP increased. The addition of GBF and CP also resulted in a decrease in the acceptance of odor and taste. This may be on account of the unpleasant astringency taste of GBF which is considered as the limitation of enrichment in food products [31]. Nevertheless, Ribeiro et al. [10] found the correlation between whole cricket and lasting aftertaste attributes in cereal-bar product. In addition, It was also observed a decrease in sensory score on flavor and overall liking. This was due to the association with negative sensory attributes including too strong odor and taste [32].

Moreover, the liking score for hardness of rice crackers declined as the GRF and CP increased, which was consistent with maximum force increase when GBF and CP shared a higher proportion of the make-up.

Table 5 Color parameters, expansion ratio, bulk density, and textural properties of glutinous rice crackers incorporated with GBF and CP.

Formula	Composition (%)			Color parameters			Expansion ratio	Bulk Density (g/cm^3)	Max Force (g)	Number of Peaks
	GRF	GBF	CP	L*	a*	b*				
F1	70.75	29.25	0	49.72±2.40^{f}	13.08±0.26^{bc}	24.62±1.01^{d}	1.57±0.27^{gh}	0.38±0.04^{c}	1265.24±251.79^{ab}	2.07±0.80^{c}
F2	75.00	17.50	7.50	49.73±1.15^{f}	14.15±0.30^{a}	26.17±1.10^{bc}	1.98±0.08^{e}	0.28±0.02^{e}	964.15±130.67^{de}	2.13±1.00^{c}
F3	92.18	1.58	6.24	57.51±0.93^{c}	12.36±0.99^{cd}	27.71±0.93^{a}	2.72±0.17^{bc}	0.18±0.01^{g}	521.52±110.38^{g}	5.47±1.80^{b}
F4	70.75	29.25	0	51.83±1.61^{e}	13.03±0.55^{bc}	25.50±0.82^{cd}	1.74±0.13^{fg}	0.33±0.02^{d}	1370.55±149.82^{a}	3.60±2.60^{c}
F5	86.00	0	14.00	54.94±1.94^{d}	11.74±1.18^{d}	27.34±1.17^{ab}	2.54±0.12^{cd}	0.22±0.02^{f}	536.96±103.58^{g}	5.60±1.50^{b}
F6	75.00	17.50	7.50	50.94±2.16^{ef}	13.86±0.81^{ab}	26.89±1.30^{ab}	1.92±0.17^{ef}	0.33±0.02^{d}	1195.96±195.48^{bc}	2.93±1.80^{c}
F7	89.38	10.13	0.49	60.13±3.31^{b}	10.90±1.27^{e}	25.25±1.24^{cd}	2.77±0.15^{b}	0.22±0.01^{f}	695.95±122.87^{f}	8.93±2.80^{a}
F8	100.00	0	0	64.39±2.15^{a}	9.31±1.28^{f}	24.66±2.21^{d}	3.94±0.25^{a}	0.17±0.01^{g}	521.47±117.74^{g}	9.20±4.20^{a}
F9	80.93	12.55	6.53	49.45±1.20^{f}	13.83±0.74^{ab}	25.53±1.03^{cd}	2.44±0.19^{d}	0.29±0.02^{e}	954.35±231.17^{de}	3.27±1.50^{c}
F10	56.12	35.00	8.88	41.51±1.31^{h}	13.23±0.61^{bc}	20.77±1.37^{e}	1.49±0.12^{h}	0.45±0.04^{b}	1060.01±311.21^{cd}	2.80±0.90^{c}
F11	56.12	35.00	8.88	41.19±0.77^{h}	12.10±0.55^{d}	19.38±1.06^{f}	1.42±0.12^{h}	0.52±0.02^{a}	849.97±84.54^{e}	2.53±0.80^{c}
F12	75.15	9.85	15.00	50.18±1.36^{ef}	13.76±0.39^{ab}	26.29±0.38^{bc}	2.11±0.22^{e}	0.33±0.02^{d}	1274.13±287.75^{ab}	3.80±2.80^{c}
F13	61.66	23.34	15.00	46.37±2.03^{g}	12.04±0.81^{d}	21.94±1.18^{e}	1.54±0.17^{gh}	0.45±0.02^{b}	922.92±199.90^{de}	2.33±1.00^{c}

Note: F4, F6, and F11 were the replicated design points of F1, F2 and F10, respectively. Values are presented in mean ± standard deviation (n=3), except dietary fiber (n=2). Different letters in the same column are significantly different ($p < 0.05$).

Table 6 Chemical properties of glutinous rice crackers incorporated with GBF and CP.

Formula	Composition (%)			Moisture content (%)	Protein (g/100g db)	IDF (g/100g db)	SDF (g/100g db)	TDF (g/100g db)
	GRF	GBF	CP					
F1	70.75	29.25	0	1.42±0.07^{b}	4.17±0.11^{f}	3.66±0.14^{bcd}	1.35±0.15^{a}	5.01±0.01^{b}
F2	75.00	17.50	7.50	1.01±0.02^{d}	7.87±0.15^{c}	3.34±0.05^{cde}	0.90±0.30^{a}	4.24±0.24^{cd}
F3	92.18	1.58	6.24	0.99±0.07^{d}	8.05±0.10^{c}	2.51±0.11^{f}	0.82±0.47^{a}	3.33±0.35^{f}
F4	70.75	29.25	0	1.76±0.12^{a}	4.23±0.01^{f}	3.89±0.37^{b}	0.72±0.13^{a}	4.61±0.50^{bcd}
F5	86.00	0	14.00	0.82±0.06^{e}	11.39±0.05^{a}	2.95±0.16^{ef}	1.00±0.47^{a}	3.94±0.31^{cdef}
F6	75.00	17.50	7.50	1.22±0.04^{c}	7.92±0.04^{c}	3.79±0.14^{bc}	0.89±0.23^{a}	4.68±0.08^{bc}
F7	89.38	10.13	0.49	1.27±0.03^{c}	5.02±0.08^{e}	2.52±0.26^{f}	0.95±0.70^{a}	3.46±0.43^{ef}
F8	100.00	0	0	1.03±0.03^{d}	5.07±0.06^{e}	1.36±0.04^{g}	0.71±0.33^{a}	2.07±0.28^{g}
F9	80.93	12.55	6.53	1.41±0.06^{b}	7.62±0.12^{d}	2.71±0.07^{f}	1.18±0.57^{a}	3.89±0.64^{def}
F10	56.12	35.00	8.88	1.44±0.03^{b}	7.47±0.12^{d}	5.01±0.45^{a}	1.11±0.46^{a}	6.11±0.01^{a}
F11	56.12	35.00	8.88	1.75±0.05^{a}	7.87±0.02^{c}	4.91±0.20^{a}	1.16±0.28^{a}	6.06±0.08^{a}
F12	75.15	9.85	15.00	1.18±0.03^{c}	11.38±0.10^{a}	3.27±0.03^{de}	0.61±0.28^{a}	3.88±0.24^{def}
F13	61.66	23.34	15.00	1.85±0.02^{a}	10.90±0.29^{b}	3.38±0.17^{cde}	0.78±0.13^{a}	4.16±0.30^{cde}

Note: F4, F6, and F11 were the replicated design points of F1, F2 and F10, respectively. Values are presented in mean ± standard deviation (n=3), except dietary fiber (n=2). Different letters in the same column are significantly different ($p < 0.05$)

Table 7 Sensory properties of glutinous rice crackers incorporated with GBF and CP.

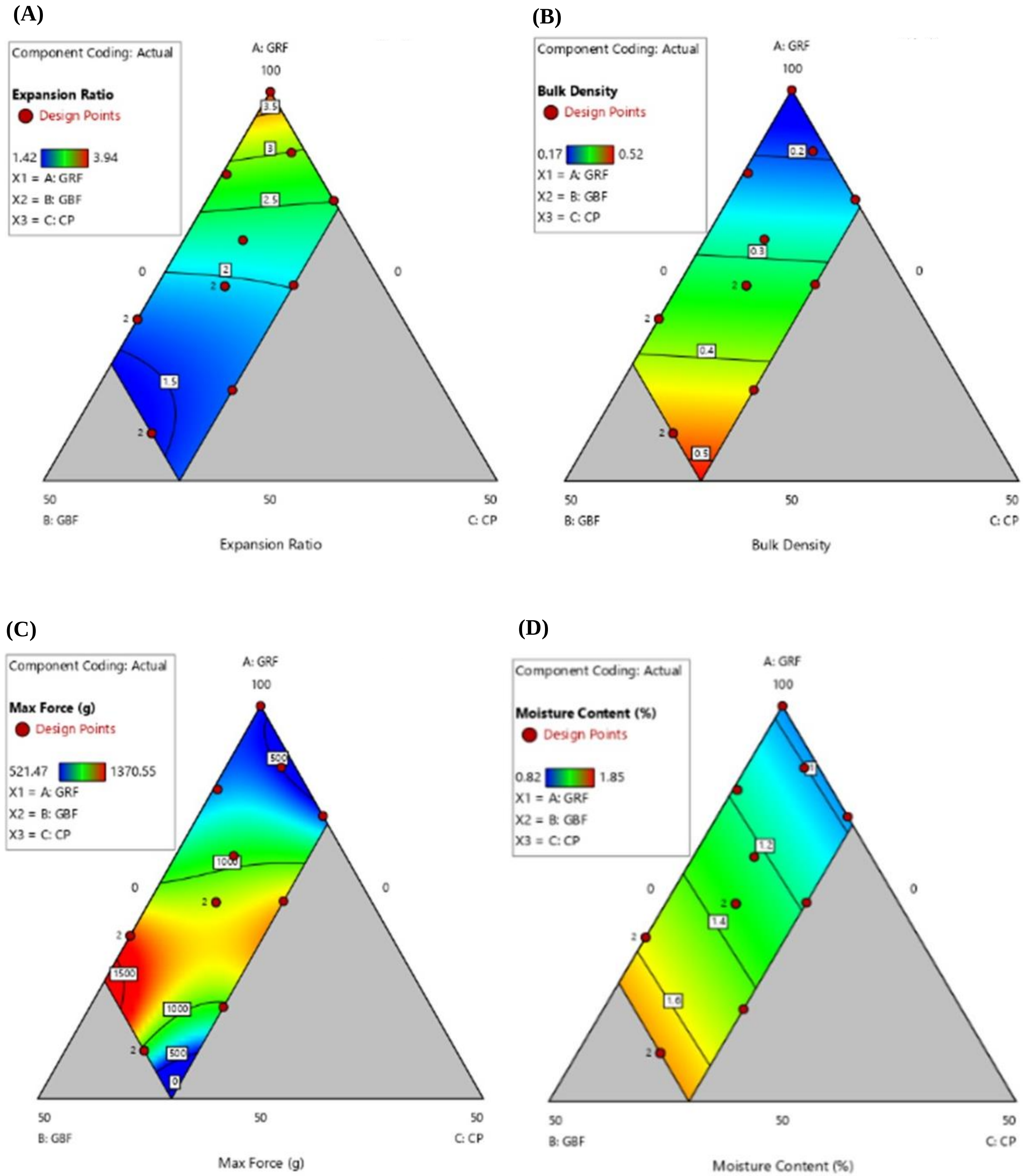
Formula	Composition (%)			Liking Score						
	GRF	GBF	CP	Appearance	Color	Odor	Taste	Hardness	Crispness	Overall
F1	70.75	29.25	0	5.94 ± 1.66^{d}	5.62 ± 1.83^{e}	6.00 ± 1.48^{ab}	6.32 ± 1.68^{abc}	6.24 ± 1.72^{bc}	6.72 ± 1.90^{de}	6.38 ± 1.56^{cd}
F2	75.00	17.50	7.50	5.26 ± 1.87^{e}	4.86 ± 2.01^{f}	4.78 ± 1.95^{de}	4.32 ± 2.15^{e}	5.86 ± 2.17^{bc}	6.34 ± 1.94^{ef}	4.92 ± 1.90^{f}
F3	92.18	1.58	6.24	6.88 ± 1.53^{b}	6.82 ± 1.48^{bc}	5.98 ± 1.73^{ab}	6.48 ± 1.74^{ab}	7.38 ± 1.40^{a}	7.56 ± 1.38^{a}	7.06 ± 1.41^{b}
F4	70.75	29.25	0	6.02 ± 1.92^{cd}	5.76 ± 1.78^{e}	5.84 ± 1.73^{bc}	5.82 ± 2.03^{cd}	5.62 ± 2.28^{c}	6.02 ± 2.33^{f}	5.86 ± 1.99^{de}
F5	86.00	0	14.00	6.58 ± 1.69^{bc}	6.44 ± 1.39^{cd}	5.32 ± 1.98^{cd}	5.38 ± 2.26^{d}	7.00 ± 1.70^{a}	7.46 ± 1.45^{abc}	6.12 ± 1.89^{cde}
F6	75.00	17.50	7.50	5.86 ± 1.56^{d}	5.70 ± 1.85^{e}	5.66 ± 1.76^{bc}	5.74 ± 1.80^{cd}	5.76 ± 2.09^{bc}	6.02 ± 2.17^{f}	5.68 ± 1.83^{e}
F7	89.38	10.13	0.49	7.12 ± 1.22^{ab}	7.06 ± 1.23^{ab}	6.52 ± 1.69^{a}	6.70 ± 1.46^{a}	7.22 ± 1.70^{a}	7.36 ± 1.70^{abcd}	7.08 ± 1.26^{b}
F8	100.00	0	0	7.64 ± 1.26^{a}	7.60 ± 1.63^{a}	6.54 ± 1.61^{a}	6.96 ± 1.56^{a}	7.44 ± 1.40^{a}	7.52 ± 1.45^{ab}	7.66 ± 1.30^{a}
F9	80.93	12.55	6.53	6.28 ± 1.51^{cd}	5.90 ± 1.84^{ef}	5.90 ± 1.74^{bc}	5.98 ± 2.03^{bcd}	6.32 ± 1.98^{b}	6.88 ± 1.89^{bcde}	6.52 ± 1.63^{c}
F10	56.12	35.00	8.88	4.64 ± 1.96^{f}	4.26 ± 2.03^{f}	4.62 ± 1.98^{e}	4.28 ± 2.12^{e}	4.44 ± 1.98^{d}	4.64 ± 2.23^{g}	4.18 ± 1.73^{g}
F11	56.12	35.00	8.88	4.66 ± 2.13^{f}	4.40 ± 1.98^{f}	4.92 ± 1.80^{de}	4.62 ± 2.07^{e}	3.98 ± 1.97^{d}	4.38 ± 2.15^{g}	4.42 ± 1.89^{fg}
F12	75.15	9.85	15.00	6.18 ± 1.45^{cd}	5.72 ± 1.71^{e}	5.32 ± 1.90^{cd}	5.54 ± 1.96^{d}	6.40 ± 1.82^{b}	6.86 ± 1.84^{cde}	5.86 ± 1.76^{de}
F13	61.66	23.34	15.00	4.90 ± 1.96^{ef}	4.52 ± 2.14^{f}	4.72 ± 2.00^{e}	4.28 ± 2.14^{e}	4.32 ± 2.04^{d}	4.62 ± 2.28^{g}	4.34 ± 1.95^{g}

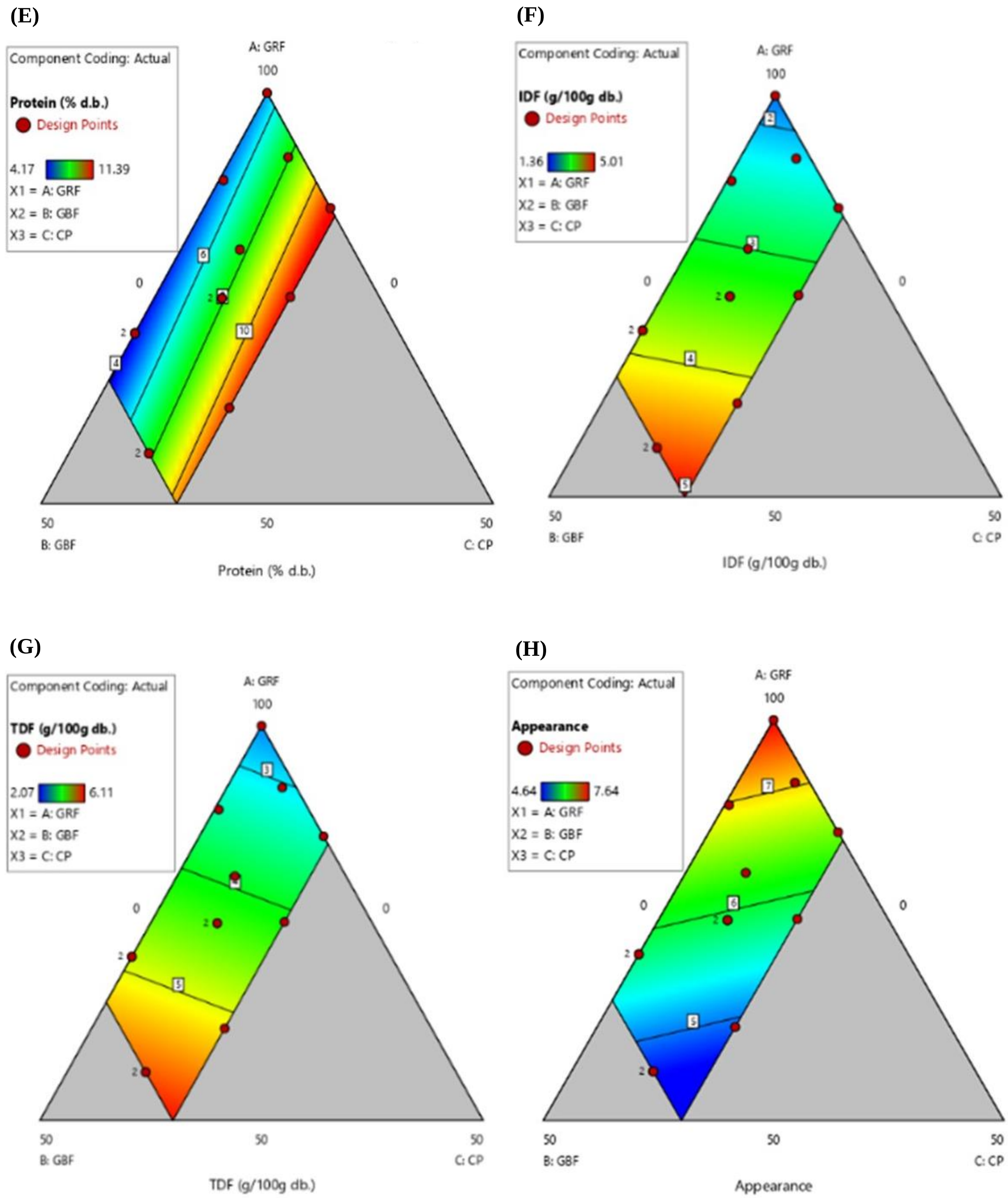
Note: F4, F6, and F11 were the replicated design points of F1, F2 and F10, respectively. Values are presented in mean ± standard deviation (n=50). Different letters in the same column are significantly different ($p < 0.05$)

Table 8 Analysis of Variance of regression models for physical, chemical, and sensory properties of glutinous rice crackers incorporated with GBF and CP.

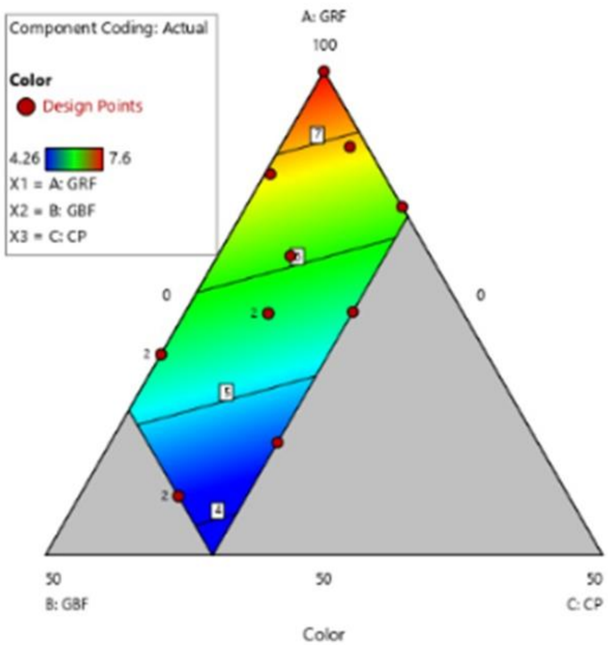
Parameters	Predictive models	R^2	p-value	Lack of fit (p)
Physical properties				
Expansion ratio	$Y = 3.95A+2.06B+25.68C-4.48AB -35.69AC-33.16BC+73.12A^2BC +64.17AB^2C-211.09ABC^2$	0.9686	<0.0001	0.0723
Bulk density(g/cm^3)	$Y = 0.14A+0.88B+0.84C$	0.9391	<0.0001	0.3230
Max Force (g)	$Y = 551.75A+10101.47B+27613.10C -9755.96AB-31246.60AC -218095.00BC +280461.00ABC$	0.9336	0.0026	0.8272
No. of Peaks	$Y = 7.85A-5.97B-10.86C$	0.6644	0.0043	0.0799
Chemical properties				
MC (%)	$Y = 0.97A+3.24B+0.41C$	0.8034	0.0003	0.6261
Protein	$Y = 5.25A+1.36B+48.89C$	0.9970	<0.0001	0.8038
IDF	$Y = 1.76A+8.74B+7.35$	0.8685	<0.0001	0.1206
SDF	$Y = 1.76A+8.74B+7.35C$	0.2123	0.3032	0.7860
TDF	$Y = 2.61A+10.32B+7.59C$	0.8407	0.0001	0.1062
Sensory properties				
Appearance	$Y = 7.66A+1.30B-0.72C$	0.9313	<0.0001	0.4614
Color	$Y = 7.60A+0.59B-2.05C$	0.9331	<0.0001	0.7496
Odor	$Y = 6.66A+3.78B+2.35C$	0.8437	<0.0001	0.8855
Taste	$Y = 7.15A+2.64B-4.57C$	0.7959	0.0004	0.8822
Hardness	$Y = 7.99A-0.17B-0.71C$	0.9120	<0.0001	0.3777
Crispness	$Y = 7.57A+0.21B+3.18C+4.75AB +5.59AC-44.57BC$	0.9617	<0.0001	0.6792
Overall liking	$Y = 7.86A+1.04B-4.34C$	0.9063	<0.0001	0.0591

A-Glutinous rice flour, B-Green banana flour, C-Cricket powder, p-probability

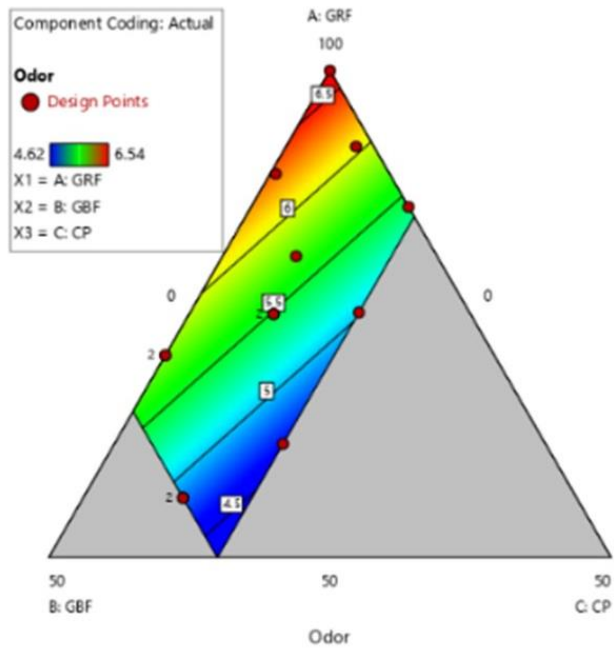

(A)
Component Coding: Actual
Expansion Ratio
Design Points
1.42
3.94
X1 = A: GRF
X2 = B: GBF
X3 = C: CP
A: GRF
100
3.5
3
2.5
2
1.5
0
0
2
2
2
50
B: GBF
50
50
C: CP
Expansion Ratio
(B)
Component Coding: Actual
Bulk Density
Design Points
0.17
0.52
X1 = A: GRF
X2 = B: GBF
X3 = C: CP
A: GRF
100
0.2
0.3
0.4
0.5
0
0
2
2
2
50
B: GBF
50
50
C: CP
Bulk Density
(C)
Component Coding: Actual
Max Force (g)
Design Points
521.47
1370.55
X1 = A: GRF
X2 = B: GBF
X3 = C: CP
A: GRF
100
500
1000
1500
1000
500
0
0
0
2
2
2
50
B: GBF
50
50
C: CP
Max Force (g)
(D)
Component Coding: Actual
Moisture Content (%)
Design Points
0.82
1.85
X1 = A: GRF
X2 = B: GBF
X3 = C: CP
A: GRF
100
1
1.2
1.4
1.6
0
0
2
2
2
50
B: GBF
50
50
C: CP
Moisture Content (%)


(E)
Component Coding: Actual
Protein (% d.b.)
Design Points
4.17
11.39
X1 = A: GRF
X2 = B: GBF
X3 = C: CP
A: GRF
100
B: GBF
C: CP
Protein (% d.b.)
(F)
Component Coding: Actual
IDF (g/100g db.)
Design Points
1.36
5.01
X1 = A: GRF
X2 = B: GBF
X3 = C: CP
IDF (g/100g db.)
(G)
Component Coding: Actual
TDF (g/100g db.)
Design Points
2.07
6.11
X1 = A: GRF
X2 = B: GBF
X3 = C: CP
TDF (g/100g db.)
(H)
Component Coding: Actual
Appearance
Design Points
4.64
7.64
X1 = A: GRF
X2 = B: GBF
X3 = C: CP
Appearance

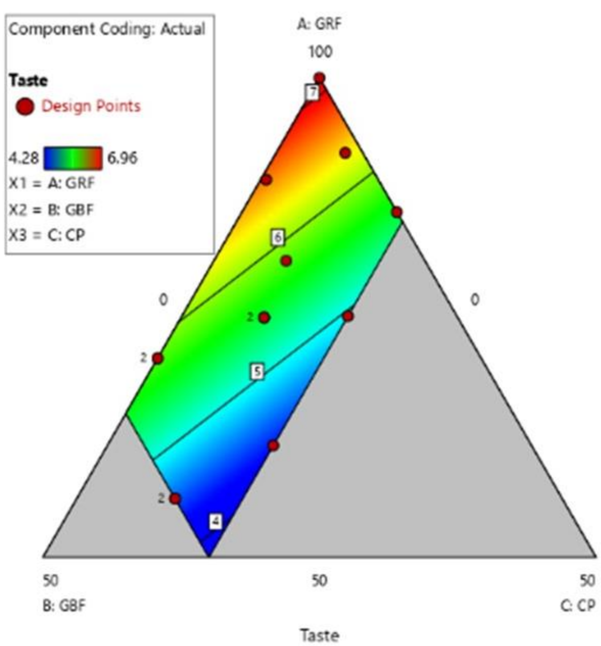
(I)


Component Coding: Actual
Color
Design Points
4.26
7.6
X1 = A: GRF
X2 = B: GBF
X3 = C: CP
A: GRF
100
0
0
50
50
50
B: GBF
C: CP
Color

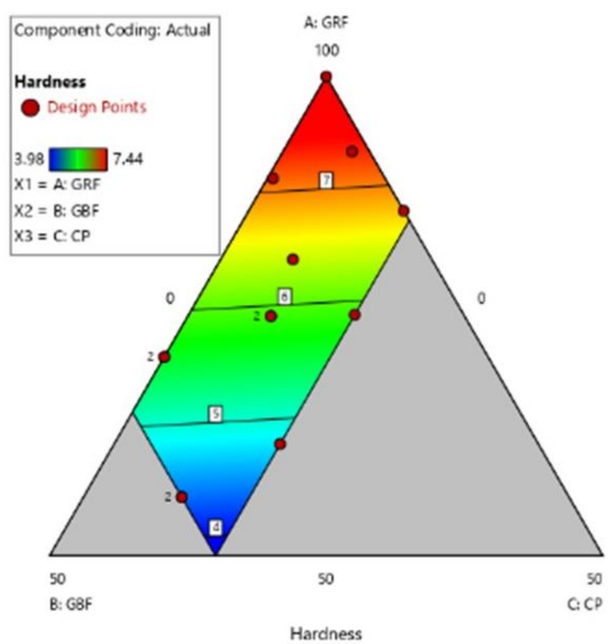
(J)


Component Coding: Actual
Odor
Design Points
4.62
6.54
X1 = A: GRF
X2 = B: GBF
X3 = C: CP
A: GRF
100
0
0
50
50
50
B: GBF
C: CP
Odor

(K)


Component Coding: Actual
Taste
Design Points
4.28
6.96
X1 = A: GRF
X2 = B: GBF
X3 = C: CP
A: GRF
100
0
0
50
50
50
B: GBF
C: CP
Taste

(L)


Component Coding: Actual
Hardness
Design Points
3.98
7.44
X1 = A: GRF
X2 = B: GBF
X3 = C: CP
A: GRF
100
0
0
50
50
50
B: GBF
C: CP
Hardness

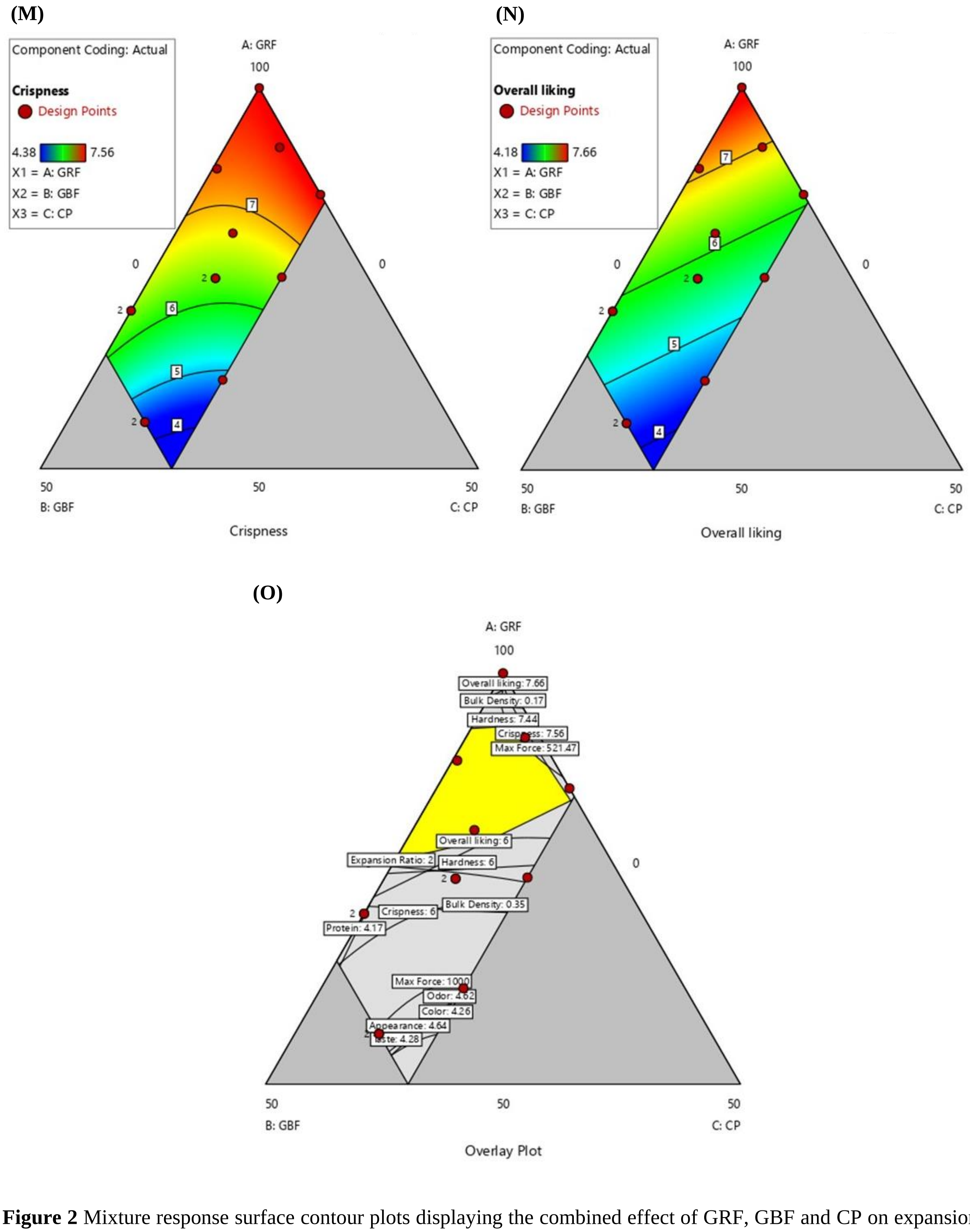


Figure 2 Mixture response surface contour plots displaying the combined effect of GRF, GBF and CP on expansion ratio (A), bulk density (B), maximum force (C), Moisture content (D), protein (E), IDF (F), TDF (G), liking score on appearance (H), color (I), odor (J), taste (K), crispness (L), hardness (M), overall liking score (N) and the obtain overlay plot (O).

3.7 *Formulation optimization*

The predicted models, coefficients of determination (R^2), probability of models (*p*-value), and lack of fit of models achieved for physiochemical properties and sensory properties are shown in Table 8. Optimization was set up on the regression model with model significance ($p < 0.05$), high coefficient of determination ($R^2 > 0.70$), and non-significant lack of fit ($p > 0.05$). Multiple optimizations for the ingredient level for rice cracker formulation were performed to maximize GBF, CP, protein content, dietary fiber, expansion ratio, and liking score along with minimizing GRF, bulk density, and hardness of rice crackers, respectively.

For physical properties, all the mathematical models were significant ($p < 0.01$) and the lack of fit was non-significant ($p > 0.05$), except the model of the number of peaks was significant but not appropriate to predict the textual property of the cracker due to the low coefficient of determination ($R^2 = 0.6644$) even though lack of fit was non-significant. The ANOVA suggested that the chemical properties of glutinous rice crackers could be explained by linear models, except the model for SDF which was not significant and lower ($R^2 = 0.3032$). All regression models of sensory attributes could be explained with high significance ($p < 0.05$). The models could optimize GBF and CP contents in formulation for glutinous rice crackers (Figure 2(A) - 2(N)). The optimal area was discovered by overlaying contour plots (Figure 2(O)) for the criteria responses and applying ingredient levels that set up limits of acceptable quality for each factor. The optimum point ingredients composition suggested by the Design Expert trial software version 12.0 (State-Ease, USA) were 78.87% GRF, 16.07% GBF and 5.06% CP which will offer the rice cracker with good textural properties (2.15 expansion ratio, 0.29 g/cm3 bulk density, and 997.70 g maximum force), nutritional value (6.83% protein and 4.31% total dietary fiber), and consumers acceptance (6.14 overall-liking score).

3.8 Relationship among pasting properties of mixed flour and textural properties of rice cracker added with GBF and CP.

Pearson’s correlation coefficients relating the pasting properties of mixed flour and the textural properties of rice crackers are listed in Table 9. It was found that peak viscosity, hold viscosity, breakdown and final viscosity were positively correlated with the expansion ratio and number of peaks of rice crackers but showed a negative correlation with maximum force and bulk density. A similar result was also observed by Saeleaw & Schleining [33] on the mixture of cassava starch, waxy rice, and wheat flour. Peak viscosity was associated with the swelling power of starch granules. The flour had a higher peak viscosity generating the greater swelling power. This indicated that starch granules swell at lower temperatures.

The expansion ratio was negatively correlated with bulk density ($r^2 = -0.862$) but showed a positive correlation with the number of peaks ($r^2 = 0.623$). With a lower expansion ratio, the cracker structure will be denser which will lead to higher bulk density. Furthermore, higher expansion resulted in a greater number of peaks. This may be due to the porous structure of rice crackers with a higher expansion ratio. In summary, to obtain rice crackers with good expansion and crispness, lower bulk density, and hardness, all pasting properties should be greater except pasting temperature.

Table 9 Pearson's correlations between pasting properties of mixed flour and textural properties and rice cracker.

	Pasting properties						Textural properties			
	Peak	Hold	Breakdown	Final	Setback	Pasting Temp.	Bulk density	Expansion ratio	Max. Force	No. of peak
Peak	1									
Hold	0.908**	1								
Break-down	0.996**	0.865**	1							
Final	0.887**	0.992**	0.843**	1						
Setback	0.687**	0.825**	0.640**	0.888**	1					
Pasting Temperature	-0.693**	-0.728**	-0.668**	-0.732**	-0.644**	1				
Expansion ratio	0.926**	0.844**	0.921**	0.829**	0.660**	-0.700**	-0.862**	1		
Bulk density	-0.861**	-0.848**	-0.843**	-0.831**	-0.653**	0.881**	1			
Max. force	-0.644**	-0.469**	-0.666**	-0.455**	-0.338**	0.308**	0.452**	-0.571**	1	
No. of peaks	0.623**	0.562**	0.621**	0.555**	0.454**	-0.500**	-0.558**	0.667**	-0.453**	1

**Correlation is significant at the 0.01 level (2-tailed).

4. Conclusion

The GRF, GBF, and CP significantly affected the quality of the cracker Pearson's correlation of the pasting property profiles with the texture of crackers was significant. Thus, pasting profiles could estimate the qualities of crackers. Incorporation of GBF and CP in the formulation resulted in enhancing the nutritional value, especially protein and dietary fiber, but increasing GBF and CP in the formulation could lead to negative physical properties such as higher hardness and lower expansion. However, GBF and CP of 16.07% GBF and 5.06% CP could enhance the nutritional value of glutinous rice crackers with consumer acceptability. Nevertheless, GBF and CP contents that were higher than 16.09% and 5.06%, respectively decreased the physical and sensorial quality of rice crackers. Therefore, exploring techniques to enrich the nutrition improvement and flavoring of rice crackers with high consumer acceptability is suggested for further studies.

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6. Conflict of interest

No conflict of interest.

7. References

[1] Thai Community Product Standards. Crisp-rice-cake (No. 107-2011) [Internet]. 2006 [cited 2020 Aug 12]. Available from: http://tcps.tisi.go.th/public/en/StandardList.aspx.

[2] Astrup A, Bovy MWL, Nackenhorst K, Popova AE. Food for thought or thought for food? – A stakeholder dialogue around the role of the snacking industry in addressing the obesity epidemic. Obes Rev. 2006;7(3):303–312.

[3] Elizabeth S. Top 10 Functional Food Trends. [Internet]. 2020 [cited 2020 Apr 4]. Available from: https://www.ift.org/news-and-publications/food-technology-magazine/issues/2018/april/features/top-10-functional-food-trends-2018.

[4] Hoffmann Sardá FA, Giuntini EB, Gomez MLPA, Lui MCY, Negrini JAE, Tadini CC, et al. Impact of resistant starch from unripe banana flour on hunger, satiety, and glucose homeostasis in healthy volunteers. J Funct Food. 2016;24:63–74.

[5] Górecki, A. R., Błaszczak, W., Lewandowicz, J., Le Thanh-Blicharz, J., & Penkacik, K. Influence of high pressure or autoclaving-cooling cycles and pullulanase treatment on buckwheat starch properties and resistant starch formation. Pol J Food Nutr Sci. 2018;68(3);235–242.

[6] Ding Y, Luo F, Lin Q. Insights into the relations between the molecular structures and digestion properties of retrograded starch after ultrasonic treatment. Food Chem. 2019;294:248-259.

[7] Van Huis A. Edible insects contributing to food security?. Agric & Food Secur. 2015;4(20):1-9.

[8] Klaus W. Lange, Yukiko Nakamura. Edible insects as future food: chances and challenges. J Future Foods. 2021;1(1);38-46.

[9] Da Rosa Machado C, Thys RCS. Cricket powder (*Gryllus assimilis*) as a new alternative protein source for gluten-free breads. Innov Food Sci Emerg Technol. 2019;56:1-7.

[10] Ribeiro JC, Lima RC, Maia MRG, Almeida AA, Fonseca AJM, Cabrita ARJ, et al. Impact of defatting freeze-dried edible crickets (*Acheta domesticus* and *Gryllodes sigillatus*) on the nutritive value, overall liking and sensory profile of cereal bars. Food Sci Technol. 2019;113:1-7.

[11] Gmuer A, Nuessli Guth J, Hartmann C, Siegrist M. Effects of the degree of processing of insect ingredients in snacks on expected emotional experiences and willingness to eat. Food Qual Prefer. 2016;54:117–127.

[12] Maiyo NC, Khamis FM, Okoth MW, Abong GO, Subramanian S, Egonyu JP, Xavier C, Ekesi S, Omuse ER, Nakimbugwe D, et al. Nutritional quality of four novel porridge products blended with edible cricket (Scapsipedus icipe) meal for food. Foods. 2022;11(7):1047.

[13] Placentino U, Sogari G, Viscecchia R, De Devitiis B, Monacis L. The new challenge of sports nutrition: Accepting insect food as dietary supplements in professional athletes. Foods. 2021;10(5):1117.

[14] AOAC. Official methods of analysis of AOAC international. Association of Official Analytical Chemists (AOAC). 17th ed. USA: Gaithersburg MD; 2000.

[15] Mir SA, Bosco SJD, Shah MA, Santhalakshmy S, Mir MM. Effect of apple pomace on quality characteristics of brown rice based cracker. J Saudi Soc Agric Sci. 2017;16(1):25-32.

[16] Narkrugsa W, Therapraserd P, Wisestherrakul P. Jellose as binder for thin-crispy cracker from black glutinous flour using microwave technique. VRU Research and Development Journal Science and Technology. 2017; 12(2):57-63.

[17] Segnini S, Pedreschi F, Dejmek P. Volume measurement method of potato chips. Int J Food Prop. 2004;7(1): 37–44.

[18] Macfie HJ, Bratchell N, Greenhoff K, Vallis LV. Designs to balance the effect of order of presentation and first-order carry-over effects in hall tests. J Sens Stud. 1989;4(2):129-148.

[19] Moongngarm A. Chemical compositions and resistant Starch content in starchy foods. Am J Agric Biol Sci. 2013;8(2):107–113.

[20] Eakkanaluksamee, K., & Anuntagool, J. Optimization of high-protein glutinous rice flour production using response surface method. Rice Sci. 2020;27(1):75-80.

[21] Montowska M, Kowalczewski PŁ, Rybicka I, Fornal E. Nutritional value, protein and peptide composition of edible cricket powders. Food Chem. 2019;289:130-138.

[22] Udomsil N, Imsoonthornruksa S, Gosalawit C, Ketudat-Cairns M. Nutritional values and functional properties of house cricket (Acheta domesticus) and field cricket (*Gryllus bimaculatus*). FSTR. 2019;25(4):597-605.

[23] Vatanasuchart N, Butsuwan P, Narasri W. Nutritional composition, in vitro starch digestibility and estimated glycemic index of three varieties of “Kluai Namwa” banana (*Musa sapientum* L.) and its products. Maejo Int J Sci Tech. 2015;9(2):265-277.

[24] González CM, Garzón R, Rosell CM. Insects as ingredients for bakery goods. A comparison study of *H. illucens*, *A. domestica* and *T. molitor* flours. Innov Food Sci Emerg Technol. 2019;51:205-210.

[25] Nimsung P, Thongngam M, Naivikul O. Compositions, Morphological and Thermal Properties of Green Banana Flour and Starch. Kasetsart J. (Nat. Sci.). 2012;46:461-472.

[26] Pongjanta, J., Chomsri, N., Siritunya, K., Chutima, L. Thanyasirin and RD6 properties. Proceedings of the 7th International Conference on Starch Technology (Starch Update 2013); 2013 November 21-22; Bangkok, Thailand. 2013. p. 200–206.

[27] Devi A, Sindhu R, Khatkar BS. Effect of fats and oils on pasting and textural properties of wheat flour. J Food Sci Technol. 2020;57(10):3836-3842.

[28] Wang S, Chao C, Cai J, Niu B, Copeland L, Wang S. Starch-lipid and starch-lipid-protein complexes: A comprehensive review. Compr Rev Food Sci Food Saf .2020;19(3):1056-1079.

[29] Katyal M, Singh N, Singh H. Effects of incorporation of groundnut oil and hydrogenated fat on pasting and dough rheological properties of flours from wheat varieties. J Food Sci Technol. 2019;56(2):1056-1065.

[30] Amini Khoozani A, Kebede B, El-Din Ahmed Bekhit A. Rheological, textural and structural changes in dough and bread partially substituted with whole green banana flour. J Food Sci Technol. 2000;126:1-7.

[31] Liao H-J, Hung C-C. Chemical composition and in vitro starch digestibility of green banana (cv. Giant Cavendish) flour and its derived autoclaved/debranched powder. J Food Sci Technol. 2015;64(2):639-644.

[32] Biró B, Sipos MA, Kovács A, Badak-Kerti K, Pásztor-Huszár K, Gere A. Cricket-enriched oat biscuit: technological analysis and sensory evaluation. Foods. 2020;9(11):1-16.

[33] Saeleaw M, Schleining G. Effect of blending cassava starch, rice, waxy rice and wheat flour on physico-chemical properties of flour mixtures and mechanical and sound emission properties of cassava crackers. J Food Eng. 2010;100(1):12–24.