International Journal of Agricultural Technology 2018 Vol. 14(3): 287-298
Available online http://www.ijat-aatsea.com
ISSN 2630-0192(Online)

Development of Extruded Ready-To-Eat Snacks from Purple Rice

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Fakfoung, S. (2018). Development of extruded ready-to-eat snacks from purple rice. International Journal of Agricultural Technology 14(3):287-298.

Abstract The objective of this study was to investigate optimum diets for extruded snacks made from purple rice. The study was performed using a simplex-lattice mixture design. The range of three ingredients was 60-70% purple rice, 12-22% corn flour and 13-23% water equivalent for a total of 100%. Data was analyzed using ANOVA; while response surface analysis was generated using the Scheffe's second degree polynomial. Results showed that changes in percentages of the three components significantly affected ($p \leq 0.05$) sensory and physicochemical properties. Predictive models were used to plot the contour line of all sensory attributes with acceptability score greater than 5.0 being selected as optimum. Resulting overlayed contour plots indicated the most ideal diet was 70% purple rice, 12% corn flour and 18% water. Instrumental texture properties for optimum extruded snacks were composed of lightness (L*) 17.09, redness (a*) 3.09 yellowness (b*) 5.38, moisture 0.79%, water activity (a_w) 0.61%, texture hardness 5.76 N. The selected diet had average score, appearance, color, flavor and overall acceptance (n = 250) in moderate levels.

Keywords: Extruded product, Snacks, Purple Rice

Introduction

Extruded ready-to-eat snack, are a growing interest among snack food consumers, due to their convenience, wide availability, appearance, taste and texture (Nicklas *et al*., 2003). Generally, extruded products are made from cereals such as corn, rice and wheat. With consumers demanding more healthy extruded snack foods, many industries have increased focus in research and product development, in able to produce products that are nutrient enriched (Brennan *et al*., 2011).

Purple rice, *Oryza sativa* is a type of sticky rice that has reddish and purple color. It is a native rice species cultivated widely in Southeast Asia (Shimoda *et al*., 2015). This rice is popularly grown in the North and Northeast regions of Thailand. They contain nutrients beneficial to health, including anthocyanin substances, which are antioxidants, common in purple rice (Matsuo *et al.*, 1997). Such antioxidants, included one in the purple rice, have been shown to reduce the incidence of serious diseases

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such as cancer (Chen *et al.*, 2006). The healthy snack food market will inevitably grow more, for both domestical and internationally markets (Food Institute, 2017). Utilizing local rice as a health food for children and adolescents is considered as an advancement that adds value and diversity to the Thai rice market. However, when using sticky rice as the main raw material in a healthy snack product, producers may face problems with product swelling, density and hardness that will be concern to consumers Keeratipibul *et al.* (2008) indicated that amounts of amylose and properties of glutinous rice had a known affect on texture of sticky rice crackers. For this reason, developmental research on purple rice snack foods was initiated; to determine optimum rice amount and proper conditions for producing the ideal snack food.

Materials and methods

Raw Materials

The main ingredient, purple rice (*O. sativa*) was obtained from a private mill in Chanthaburi, Thailand. It was cooked using an electric rice cooker, before being mixed and extruded. All other ingredients, including corn flour, barbecue seasoning powder, salt and sugar, were purchased from a local market.

Preparation of Extruded Snacks

All ingredients of each formula were mixed well, prior to passing the mixture through a single screw laboratory extruder (Brabender 20DN, model 8-235-00, Duisburg, Germany), with a screw speed of 200 rpm. The extruded materials was manually cut into strips approximately 6 cm long. The cuttings were dried in the air convection oven at 60˚C for 30 min; and then deep fried with palm oil, at 230˚C for 35 seconds. They were then set aside on racks, for 5 min to drain excess oil. Finally, the strips were mixed with barbecue seasoning powder, using a ratio of 5 gram of seasoning per 100 grams of snack product; then stored in individually sealed aluminum foil bag, until analysis.

Experimental Design

The study focused on determining appropriate formulas for extruded ready-to-eat snacks from purple rice, using the Mixture design. The trial was conducted with different proportions of cooked purple rice, corn flour and water, by constrained simplex lattice mixture design (Montgomery, 2005). The range of proportional ingredient consisted of 60-70 percent purple rice (X_1), 12-22 percent of corn flour (X_2) and 13-23 percent of water (X_3), by

$X_1+X_2+X_3 = 100$. The number of formulas used in the study were calculated from $n = 2^q - 1$, where n was the number of formulas and q was the number of ingredients. Therefore, in this trial, the number of formulas is $2^3-1=7$. However, another three formulas were provided, considered from middle of the below. All 10 formulas are listed in the table 1. Other ingredients, such as sugar (2%) and salt (1%), are constant, so remain unchanged in all formulas.

Table 1. Formulation for Different Proportions of Purple Rice, Corn Flour and Water

Formulas	Materials (%)		
	Purple rice	**Corn flour**	**Water**
1	65.10	17.12	17.78
2	69.94	12.00	18.06
3	64.71	22.00	13.29
4	63.22	13.79	23.00
5	66.69	12.53	20.78
6	68.24	15.20	16.57
7	63.17	20.32	16.51
8	60.00	21.99	18.01
9	67.26	19.26	13.49
10	70.00	16.64	13.36

Physical and Chemical Quality Analysis and Sensory Evaluation

Physicochemical characterization of the products

Fracturing of the sample products were measured using a Texture Analyzer with spherical and blade probes respectively. Lightness ($L*$), red/green chromaticity ($a*$) and yellow/blue chromaticity ($b*$) were determined, using a Hunter Lab colorimeter Model 45/0L (Hunter Associates Lab., Ind., USA). Water activity (a_w) was determined by the chilled mirror technique using an Aqualab CX-2 water activity meter (Decagon Devices Inc., Pullman, Wash., USA). Moisture was determined according to AOAC standard methods (Association of Official Agricultural Chemists, 2010). Values obtained from all formulas were analyzed using the analysis of variance (ANOVA). Significant difference among treatment means were determined, using Duncan's new multiple-range test (DMRT) at a confidence level of 95%.

Sensory evalation

Photographs of samples used for the sensory analysis have been shown in Fig. 1. Quantitative descriptive analysis was applied to evaluate sensory qualitative of the samples in terms of color, rice seed inflation, aroma, saltiness and sweetness and crispness. Twenty trained and experienced panel members were selected to participate in the development of sensory profiles for the ten different snack product formulas. Line scale (1-9) was used to ensure consistency between panelists across repeated evaluation. Randomized complete block design and statistical package (SPSS) were *used to perform* the sensory evaluation analysis.

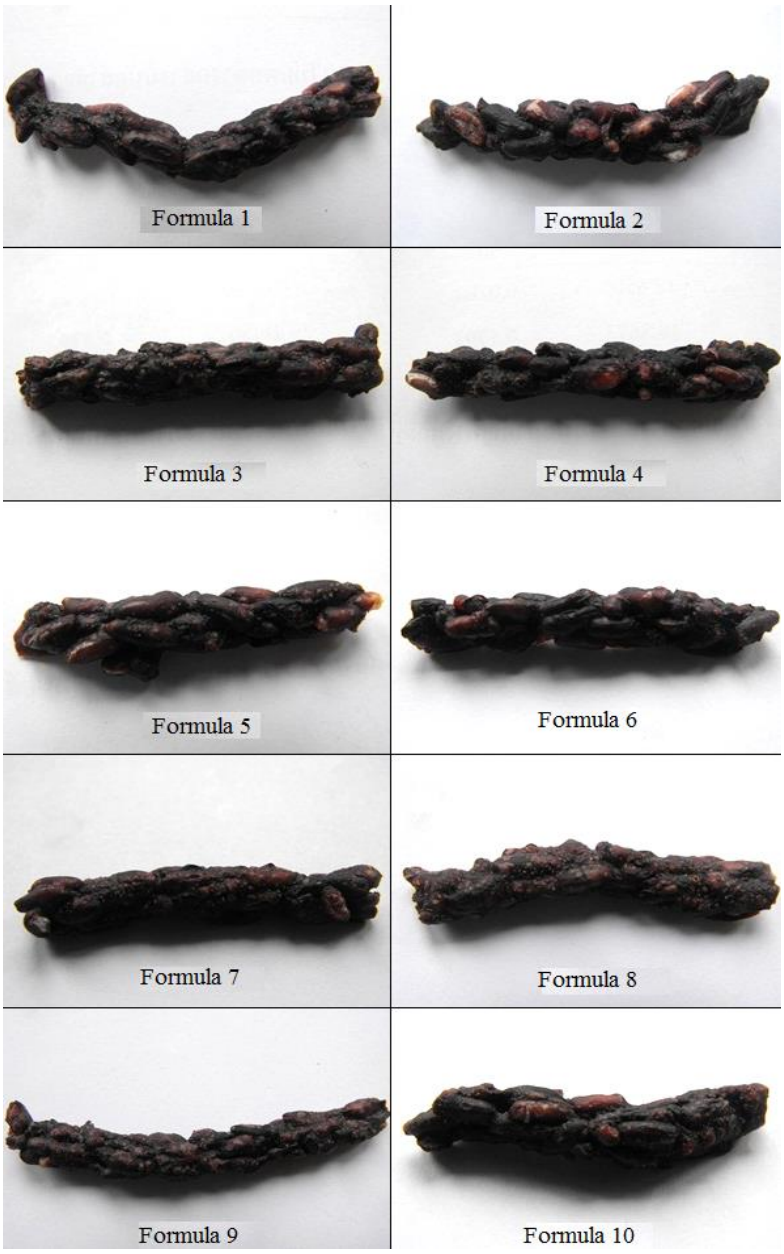

Figure 1. Photographs of each formula product samples, evaluated by the sensory panel

Selection of the best formula

The simplex-lattice mixture design method was used to determine optimum proportions of purple rice, corn flour and water. The canonical polynomial model proposed by Scheffe was used for describing responses of the mixture system. Mixture experimental design assumes equation, in the following form; $y = \beta1_{X1} + \beta2_{X2} + \beta3_{X3} + \beta4_{X1X2} + \beta5_{X1X3} + \beta6_{X2X3}$, where y is quality parameter, β is coefficient of variation, X_1 is amount of purple rice, X_2 is amount of corn flour and X_3 is volume of water. The regression equation was used to create contour plots, with results shown in Figure 1.

A consumer acceptance test

Hedonic tests were completed, to assess acceptability of various purple rice snack samples with consumers. Two hundred-fifty untrained panelists, consisting of one hundred and thirteen male and one hundred thirty-seven female, ages ranging between 17 and 27 years, were selected from students and staff of Rajamangala University Tawan-ok, Chanthaburi Campus. Panelists relied on the hedonic scale (i.e., 9 = like extremely, 5 = neither like nor dislike, and 1=dislike extremely) to evaluate each sample, for sensory characteristics of flavor, texture, color, and overall acceptance.

Results

Physicochemical properties of the products from 10 formulas

Physicochemical properties are shown in Table 2, having statistically significant differences ($p \leq 0.05$) in all proportion. Lightness (L*) lower is in formula 4 and 5, indicating that these products have a lower degree of whiteness than the others. Within the range of red (+a*) to green (-a*) tonality, green was more predominant, with formula 3 7 and 8 having the most intense tone. As for the range of yellow (+b*) to blue (-b*), highest yellowness (b*) values were observed in formula 10.

Moisture content values were in a range of 0.22-0.84%, and water activity (a_w) content ranging from 0.64-0.68%, indicating all formulas were classified as intermediate moisture foods (Jay *et al.*, 2005). Products from formula 4, 8 and 10 were crispest, due to their lower fraturing value, in comparison to the other fomulas.

Sensory Scores

The panelist sensory scores of their evaluation for each product formula are shown in Table 3; have significant statistical differences ($P \leq 0.05$) among formulations. The average preferred scale of the Formula 2 showed highest in rice seed inflation, aroma, saltiness, sweetness and crispiness; with score of 5.80 6.00 6.00 5.85 5.45 and 5.45, respectively. Whereas, the highest score of color was observed in Formula 3, with a score of 6.40.

Table 2. Physicochemical Properties of the Product from 10 Formulas

Formulations	Color[2]			Fracturability (N)	Moisture(%)	Water Activity (%)
	L*	a*	b*			
1	7.87±0.99^{a}	-1.05±1.40^{ab}	-0.35±0.63 ^{c}	7.16±0.73^{d}	0.41±0.01^{cd}	0.65±0.01^{cde}
2	6.66±0.33^{abc}	-1.83±0.31^{abc}	0.06±0.26^{bc}	5.98±0.88^{de}	0.71±0.0 5^{b}	0.64±0.01^{f}
3	6.51±0.45^{abc}	-0.10±2.98^{a}	0.73±0.93^{abc}	11.41±0.40^{a}	0.52±0.10^{c}	0.68±0.01^{a}
4	4.91±0.23^{d}	-4.01±0.50^{c}	0.19±0.34^{bc}	5.57±0.37^{e}	0.22±0.02^{e}	0.65±0.01^{def}
5	4.73±1.06^{d}	-2.60±0.30^{bc}	1.11±0.10^{ab}	10.03±0.83^{b}	0.32±0.05^{de}	0.66±0.00^{bc}
6	6.85±0.80^{ab}	-3.78±0.80^{c}	1.37±0.69^{ab}	6.53±0.49^{de}	0.80±0.44^{ab}	0.64±0.01^{ef}
7	7.63±0.37^{a}	-0.24±0.55^{a}	0.22±1.06^{bc}	8.61±0.40^{c}	0.47±0.10^{c}	0.66±0.01^{cd}
8	7.49±0.92^{a}	-0.43±0.60^{a}	0.62±0.75^{abc}	5.70±0.71^{e}	0.84±0.11^{a}	0.67±0.01^{a}
9	6.04±1.04^{bcd}	-2.61±0.52^{bc}	0.75±0.25^{abc}	6.64±0.80^{de}	0.75±0.56^{ab}	0.68±0.00^{a}
10	5.38±0.26^{cd}	-3.23±0.45^{c}	1.82±1.04^{a}	5.72±0.58^{e}	0.48±0.21^{c}	0.67±0.01^{ab}

** All data are the mean ± SD of three replicates. Mean followed by different letters in the same column differs significantly ($p \leq 0.05$)

Table 3. Hedonic Panelist Scores, Regarding Sensory Evaluation for Each Product Formulation.

Formulations	Ingredients *(%)			Characterization					
	X_1	X_2	X_3	Color	Inflation	Aroma	Saltiness	Sweetness	Crispiness
1	65.10	17.12	17.78	5.75 ± 2.51^{ab}	4.80 ± 2.09^{abc}	5.60 ± 2.64^{a}	4.85 ± 2.48^{abc}	3.85 ± 2.13^{de}	3.90 ± 2.59^{bcd}
2	69.94	12.00	18.06	5.95 ± 2.24^{ab}	5.80 ± 1.82^{a}	6.00 ± 2.22^{a}	6.00 ± 2.47^{a}	5.85 ± 2.28^{a}	5.45 ± 2.63^{a}
3	64.71	22.00	13.29	6.40 ± 2.50^{a}	3.55 ± 1.70^{d}	4.20 ± 2.28^{b}	3.95 ± 1.79^{c}	3.70 ± 2.11^{e}	3.15 ± 2.32^{d}
4	63.22	13.79	23.00	5.80 ± 2.44^{ab}	4.00 ± 1.34^{cd}	5.80 ± 2.04^{a}	4.20 ± 1.96^{bc}	4.60 ± 2.26^{bcde}	4.75 ± 2.65^{abc}
5	66.69	12.53	20.78	4.60 ± 2.39^{b}	5.50 ± 2.01^{ab}	5.45 ± 2.56^{ab}	5.25 ± 2.86^{ab}	5.45 ± 2.72^{ab}	5.25 ± 2.69^{ab}
6	68.24	15.20	16.57	5.90 ± 2.77^{ab}	4.55 ± 1.99^{bcd}	5.55 ± 2.26^{ab}	5.10 ± 2.05^{abc}	5.30 ± 2.11^{abc}	3.85 ± 2.80^{bcd}
7	63.17	20.32	16.51	5.70 ± 2.16^{ab}	4.50 ± 1.96^{bcd}	5.20 ± 2.14^{ab}	4.00 ± 2.10^{bc}	4.20 ± 2.14^{cde}	4.15 ± 2.82^{abcd}
8	60.00	21.99	18.01	4.95 ± 2.16^{b}	4.80 ± 1.96^{abc}	5.25 ± 2.61^{ab}	5.10 ± 2.02^{abc}	4.30 ± 1.95^{bcde}	4.10 ± 2.57^{abcd}
9	67.26	19.26	13.49	5.40 ± 2.33^{ab}	4.30 ± 1.78^{cd}	5.25 ± 2.05^{ab}	4.95 ± 1.79^{abc}	4.50 ± 2.12^{bcde}	3.55 ± 2.56^{cd}
10	70.00	16.64	13.36	5.60 ± 2.66^{ab}	4.95 ± 1.50^{abc}	4.90 ± 2.13^{ab}	4.30 ± 2.16^{bc}	4.90 ± 2.53^{abcd}	3.95 ± 2.48^{bcd}

* X_1 = Purple rice, X_2 = Corn flour, X_3 = Water
Data of characterization are the mean ± SD of three replicates. Mean followed by different letters in the same column differs significantly ($p \leq 0.05$)

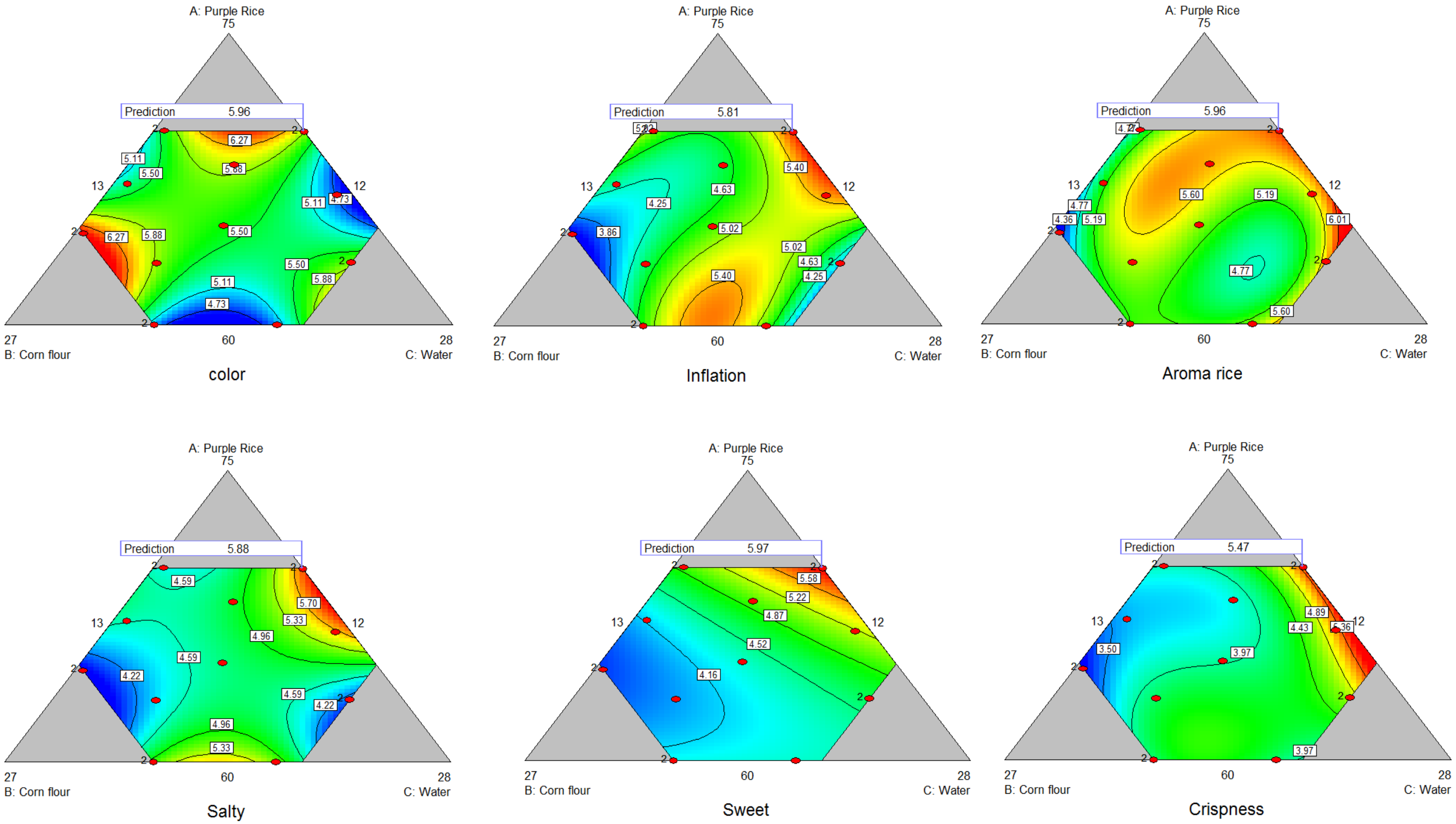

Figure 2. Response surface plots by hedonic panelist scores, for color, inflation, aroma, saltiness, sweetness, and crispness.

Since there was significant difference in preferred score among these ten formulas, it would indicate a correlation between the sensory factors and product quality. The quadratic model was then generated using data form sensory score, to describe the relationship between factors and the product quality (Table 4).

Table 4. Regression Equations of Hedonic Scores of the Panelists

Parameter	Regression Equations	R^2
Color	$(2.21X_1)+(17.15C)+(47.42X_3)–(0.28X_1C)–(0.09X_1X_3)–(1.88CX_3)+(0.03X_1CX_3)–(1.67x10^{-3})X_1.C\ (X_1\text{-}C)+(3.17x10^{-3})X_1X_3(X_1\text{-}X_3)\ –(1.56x10^{-3})CX_3(C\text{-}X_3)$	0.979
Inflation	$(2.22X_1)\text{-}(38.98C)\text{-}(85.33X_3)+(0.66X_1C)+(1.49X_1X_3)+(1.99CX_3)–(3.87x(^{3-}10X_1C)\ x\ (X_1\text{-}\ C)–\ \ 8.51x\ (^{3-}10X_1X_3(X_1\text{-}X_3)\ (\ 2.53\ x\ (^{3-}10CX_3(C\text{-}X_3)$	0.999
Aroma	$(1.95X_1)\text{-}(22.87X_2)+(79.55X_3)\text{-}(1.36X_1X_3)\text{-}(0.62X_2X_3)+(2.77x10^{-3})X_1X_2X_3–\ (7.76x10^{-3})\ X_1X_2(X_1\text{-}X_3)+(8.01x10^{-3})X_{1X}3(X_1\text{-}X_3)+(0.01x10^{-3})X_2X_3\ (X_2\text{-}X_3)$	0.955
Saltiness	$(1.80X_1)–\ (16.93X_2)–(17.90X_3)+(0.31X_1X_2)+(0.33X_1X_3)+(1.24X_2X_3)–(0.02X_1X_2X_3)$	0.909
Sweetness	$(0.31X_1)+(1.41X_2)+(0.24X_3)\text{-}(0.03X_1X_2)\text{-}(9.54x10^{-3})X_1X_3)\text{-}(1.77x10^{-3})X_2X_3)$	0.910
Crispiness	$(2.10X_1)\text{-}(49.56X_2)\text{-}(20.55X_3)+(0.83xX_1X_2)+(0.38xX_1X_3)+(0.91X_2X_3)–(5.59x10^{-3})X_1X_3–(5.06x10^{-3})X_1X_2(X_1\text{-}X_2)–(313x10^{-3})X_1X_3(X_1\text{-}X_3)+\ \ \ (4.86x10^{-3})X_2X_3\ (X_2\text{-}X_3)$	0.999

X_1 = Purple rice, X_2 = Corn flour, X_3 = Water

The response surface from overlay contour plot of color, inflation, aroma, saltiness, sweetness, and crispness are 5.96, 5.80, 5.95, 5.88, 5.97 and 5.47, respectively, which matched the second formula. Thus, it was concluded that formula 2 could offer a respectable extruded ready-to-eat snack when using purple rice. The instrumental texture properties of final extruded snack were composed of lightness (L*) 17.09, redness (a*) 3.09 yellowness (b*) 5.38, moisture 0.79 %, water activity (aw) 0.61%.

Consumer acceptance for the final product

Hedonic ratings were obtained for extruded samples, using purple rice, corn flour, water at a ration of 70% : 12% : 18%. Mean hedonic acceptance ratings for aroma, tastiness, crispiness and overall acceptance were above the moderate point (Table 5). One exception was ratings for color, which were slightly above the neutral point (5.0), but below “like slightly” (6.0).

Table 5. Mean Acceptability Consumer Score for Extruded Ready-To-Eat Snacks made from Purple Rice

Sensory	Score	Meaning
Color	5.54 ±1.53	neutral
Aroma	6.94 ±1.13	moderately like
Tastiness	7.12 ±1.26	moderately like
Crispiness	7.18 ±1.32	moderately like
Overall acceptance	7.28 ±1.01	moderately like

Discussion

It was found that the different ingredient proportions resulted in product quality difference (Table 2). Extruded snacks for all formulas were dark in color, influenced by the purple pigments in the rice. As the level of corn flour decreased (approximately 12 %) and amount of water increased (18-20%) for all percentage levels, the extruded snack, made from purple rice, exhibited less light color. This is because the color of the pueple rice becomes prominent when the color of corn flour is reduced. Moreover, since the color of purple rice is opaque, it makes the product darker. Texture analysis results showed that the fracturability (ability to break food into pieces) for all of the extruded snack products, was very low. This could be associated with low water content in this type of product. However, a low fracture force is desirable, for consumption of snacks (Roopa *et al.*, 2009).

Sensory results found that when level of corn flour decreased (approximately 12 %) and amount of water increased (18-20%) for all percentage levels, the preferred score of rice seed inflation and crispiness increased significantly. Fine particles of corn flour have better water absorption properties than rice seed: therefore, the product loses water to the flour rather than to the rice seed. It was noticed that preferred scores for rice seed inflation and crispiness were very low in formulas containing higher percentages of corn flour and less water. In general, there were no significant difference ($P > 0.05$) in taste and color detected among all ten formulas. Since sugar and salt were equal for all formulas, taste was not different. However, preferred scores for sweetness tended to become higher when using increasing levels of purple rice.

Sensory scores for color, inflation, aroma, tastiness and crispness were highest in Formula 2, containing 70% purple rice, 12% corn flour and 18% water. Mean hedonic score for all characteristics were slightly below the medium point (6.0). However, when extruded snacks from the second formula were reproduced for testing of consumer acceptance, mean hedonic score for aroma, tastiness and crispiness increased. One exception was color; which showed contrasting or lower hedonic scores. The first consumer evaluation used trained and experienced panelists, who were screened on all test criteria. They had prior information about purple rice and knew what was expected during the test. Whereas, the second evaluation used untrained panelists, who had no previous knowledgeof purple rice.This may have resulted in their decision to lower scores for color. Color is critical and often the basis for consumer selection or rejection of products (Mendoza *et al.*, 2007); therefore improvements to color quality should be further researched. Results of hedonic acceptance testing, showed moderate preference among 250 untrained panelists However, most panelists stated that if this product was sold in the market, they would likely buy, as this product is a novelty, nutritious and its taste is acceptable.

Acknowledgement

Financial support from The Rajamangala University Tawan-ok is gratefully acknowledged. The authors would like to extend their warmest gratitude to Mr. Eric Hutchings, for his review assistance.

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(Received: 13 January 2018, accepted: 28 March 2018)