Kasetsart J. (Nat. Sci.) 34 : 279 - 288 (2000)

Development of Corngrit-Broken Rice Based Snack Food by Extrusion Cooking

Pracha Boonyasirikool and Chulaluk Charunuch

ABSTRACT

Six formulas of corn-based snack were formulated with various ratios of corngrit : calcium carbonate ($CaCO_3$) : soybean oil. Extrusion processes were conducted by feeding each formula into an extruder at 444 g/min feed rate, employing 300 rpm. Moisture content of the raw materials were adjusted to 16.0±0.5%, with melt temperature of 156–158°C. The product samples exhibiting best physical properties composed of 93 % corn grit, 1 % $CaCO_3$ 2 % soybean oil, 3 % sugar and 1 % vitamins and minerals mixtures, which was coded as C_6 and exhibited an expansion ratio (E.R.) of 3.90, bulk density (B.D) 70 g/L and compression force (C.F) 69.2 N. However, C_6 corngrit based snack samples possessed the characteristics of overexpanded, crisp friable mouthfeel, orange – yellowish in color and lack of corn odor. Therefore, further developing of C_6, subsequently renamed as CR'_0 was undertaken by substituting 10 – 80 % of corn grit with broken rice, resulted in 17 formulas. The corngrit-broken rice snacks were examined for physical properties and then coated with chicken flavor prior to subject to sensory evaluation. Extruded samples produced from 50% of broken rice substitution (CR'_5) was detected to decrease E.R value (3.70) and increase B.D (76.60 g/L) and C.F (96.5 N.) compared to those samples of CR'_0. Among 17 formulas, CR'_5 gained the highest scores in flavor and texture preference with the overall acceptability of 7.05, 7.05 and 7.15 (9–point hedonic scale) respectively, which were significantly different at $P \leq 0.05$. However, color was not significantly different at $P \leq 0.05$ as compared to CR'_0.

Key word : direct expanded snack, corngrit-broken rice based snack, corn grit, broken- rice, $CaCO_3$, soybean oil.

INTRODUCTION

Extruded snacks possess the typical texture of puffed, light and crispy. Some physical properties of extruded snack were reported including bulk density of 48-64 g/L, 50-160 g/L (Moore, 1994) and 59±10g/L (Boonyasirikool, *et al.* 1996) and expansion ratio of 3.06-3.83 (Mohamed, 1990) and 4.03 ± 0.2 (Boonyasirikool, *et al.* 1996). Since extruded snacks come in a variety of shape, texture and flavor, they become popular all over the world, including Thailand. The frequency of snack consumption was surveyed in children at the age of 7-18 living in Bangkok. It was found that 51.3 % consumed snack every day, 18.8 % consumed once in a couple of days and only 5% never consumed snack before. The survey, thus, indicated a high frequency of snack consumption in children

Institute of Food Research and Product Development, Kasetsart University, Bangkok 10900, Thailand.

(Sinthavalai, 1984). In 1995, market size of snacks in Thailand was 5,820 million baht in which 40% was shared by extruded snack (Kosayothin, 1996).

Extrusion is regarded as one of the sophisticated food processing since the process enables mixing, kneading, cooking and forming to take place continually by using a single machine and complete within a short time. Moreover, it offers significant economic advantages accruing from decreased energy and floor space requirement and product quality can be improved through better process uniformity and control (Miller, 1988).

In general, direct expanded snack is mostly made from corn-grit while the use of broken rice is relatively seldom. Expanded corn curl made from collet extruder was first commercially developed in 1946 by Adams Corp., USA (Harper, 1981) and the development has been continuing to present days. The favorable characteristics of corn are yellow in color with a unique corn flavor with good puffing property. Unfortunately, the quality of corn grown in Thailand is different, especially in flavor that the similar flavor coatings is not applicable. On the other hand, rice, as a raw material for extrusion, offers a relatively good puffing quality with bland flavor suitable for coating with numbers of flavorings (Moore, 1994). It has confirmed that, the typical crispy and dense texture with milder flavor and color could be achieved by utilizing rice. In addition, rice encourages snacks to secure integrity during storage (Matz, 1984, Pongsawatmanit and Boonyasirikool, 1998). Although rice contained less protein content (8.5%) than corn-grit (9.97%), chemical score of rice protein was discovered to be 64, while the score of corn-grit was 31 (Prabhavat *et al.*, 1996). Additionally, in Thailand, for an economical advantage, rice, especially, broken rice is cheaper than corn-grit. For extrusion process, partial substitution of broken rice to corn grit could lead to the improvement in texture, density, color and alternative flavors, resulted from a milder flavor of rice that did not limit to the coating of only cheese flavor widely applied to match with corn flavor. Therefore, the increase in consumer acceptance could be expected.

The objective of this research was to develop a basic formula for producing a standard corn based snack. The development was undertaken by optimizing the proportion of corn grit: calcium carbonate: soybean oil. Subsequently, an optimum percentage of broken rice substitution in the standard corn-based snack was studied. Several attributes were taken to consideration including physical properties and sensory evaluation. It hoped was to promote the utilization of broken rice as a substituting raw material in corn based snack that would be beneficial for consumers, snack processors and the most important is to add value to broken rice.

MATERIALS AND METHODS

Corn grit (30-50 mesh), ground broken rice (30-50 mesh) and calcium carbonate (food grade) were supplied by Thai Maize Products Ltd., Saeng Ruang Flour Mills. and Thai Food and Chemicals Ltd. respectively. Cooking soybean oil was purchased locally (Grape brand).

1. Development of a basic formula for a standard corn based snack

The percentage of refined sugar and a mixtures of vitamins and minerals was fixed at 3 and 1 % respectively, through out the study. The rest of 96 % of ingredients was studied as formula C_1, C_2, C_3, C_4, C_5, and C_6 which comprised of corn grit, calcium carbonate and soybean oil. (Table 1.)

1.1 Raw material preparation

The weighed raw materials were thoroughly mixed by a mixer before transferred in a plastic bag to a co-rotating twin screw extruder (ZE 25 x 33D, Hermann Berstorff Laboratory).

Table 1 Ingredients, moisture content and physical properties of corn-grit based snack foods.

Formula (Code)	Ingredients in 6 formulae (%)					Physical properties		
	Corn grit	$CaCO_3$	soybean oil	Sugar	Mixture Of Vitamins and minerals	Bulk density (g/L)	Expansion ratio	Maximum compression force (N)
C_1	91	3	2	3	1	72.2	3.40	96.5
C_2	92	3	1	3	1	73.1	3.33	112.1
C_3	92	2	2	3	1	72.6	3.48	93.6
C_4	93	2	1	3	1	73.0	3.45	98.7
C_5	94	1	1	3	1	71.8	3.75	79.3
C_6	93	1	2	3	1	70.0	3.90	69.2

1.2 Extrusion procedure

The extruder composed of 7 connecting barrels and a 25 mm thick die with the diameter of 3.00 mm. The length/diameter ratio was 870: 25. The temperatures in the barrel no. 1-7 and no.9 (at die) were 30, 35, 45, 95, 135, 155, 130 and 120°C respectively, from the feeding port to the die section. The die plate had one circular die with one hole. The hole was initially 25.5 mm in diameter, tapered to 3.00 mm. downstream in a distance of 24 mm, and then 3.00 mm in diameter for another 5.00 mm further downstream (land length). The mixture of raw materials were fed into the extruder with a volumetric twin screw feeder (K-Tron soder AG 5702, type 20, Switzerland) which was maintained at the rate of 444 g/min. Moisture content of the feed was adjusted to 16 ± 0.5 % (wb) by injecting an ambient temperature water. Screw speed was 300 rpm (Boonyasirikool, Charunuch and Phongpipatpong,1996). The adjustable die face cutter with one blade was operated at 300 rpm. The melt temperature was 156-158°C. The extruded products were furtherly dried at 80°C for 15 min in an electric oven. The dried extruded products were allowed to cool to room temperature and immediately packed airtight in plastic bags and stored at room temperature. Samples were subjected to analysis of moisture content, and physical properties and were evaluated to select the best formula as a standard formula for corn based snack.

2. Formulation of corn based snack substituted with broken rice

A basic formula obtained from step 1 was recoded as CR_0'. The study was to investigate an optimum percentage of broken rice substitution ranging from 10 to 80 % and coded CR'_1, CR'_2, CR'_3, CR'_4, CR'_5, CR'_6, CR'_7 and CR'_8. The formulas with the absence of soybean oil were correspondingly studied and were coded CR_1, CR_2, CR_3, CR_4, CR_5, CR_6, CR_7 and CR_8 accordingly to CR'_1-CR'_8, thus, resulted in a total of 17 formulas including CR_0' (Table 2).

Raw materials preparation, extrusion processing and physical property examinations were performed identically to the previous step. Sensory evaluation was performed on product samples (70%) coated with smoked chicken powder

Table 2 Physical properties of corn based snacks substituted with broken rice.

Formula	Proportion of corn grit: broken rice	soybean oil (%)	CIE color value			Expansion ratio	Bulk density (g/L)	Maximum compression force(N)
			L*	a*	b*			
CR'_0	100 : 0	2	87.20	3.76	33.81	3.85	74.00	86.4
CR'_1	90 : 10	2	88.79	2.82	30.27	3.76	75.48	87.3
CR'_2	80 : 20	2	88.97	2.78	29.94	3.76	76.83	89.5
CR'_3	70 : 30	2	89.44	2.42	28.22	3.75	76.40	92.1
CR'_4	60 : 40	2	89.53	2.88	28.37	3.71	75.95	93.3
CR'_5	50 : 50	2	89.66	2.29	25.67	3.70	76.60	96.5
CR'_6	40 : 60	2	89.66	2.16	23.95	3.63	85.40	97.9
CR'_7	30 : 70	2	89.53	1.78	22.11	3.59	90.20	109.8
CR'_8	20 : 80	2	90.03	1.21	19.91	3.52	91.50	111.0
CR_1	90 : 10	0	88.85	2.69	28.63	3.50	89.00	97.7
CR_2	80 : 20	0	88.99	2.29	26.82	3.43	92.20	112.1
CR_3	70 : 30	0	89.23	1.99	26.22	3.36	96.34	127.6
CR_4	60 : 40	0	89.34	1.78	23.65	3.32	100.00	132.1
CR_5	50 : 50	0	90.26	0.95	19.35	3.30	101.70	146.4
CR_6	40 : 60	0	90.90	0.51	16.25	3.28	103.39	153.8
CR_7	30 : 70	0	91.07	0.36	15.28	3.28	102.44	159.1
CR_8	20 : 80	0	91.46	0.00	12.99	3.28	103.90	165.6

CIE color value : L* = lightness, 100 = white, 0 = black
a* = Redness, - = green, + = red
b* = Yellowness, - = white, + = yellow

flavor (17.5%) and soybean oil (12.5%).

3. Examination of physical properties

Expansion ratio (ER) of extruded samples was examined by applying a micrometer to measure the diameter of a cylindrical shape sample. Ten measurements were averaged.

$$ER = \frac{\text{diameter of the cylindrical sample (mm)}}{\text{diameter of the die (mm)}}$$

Bulk density (BD) of extruded samples was measured by filling a 4000 ml cup and determine the weight per volume (g/L).

Color intensity was determined by a color meter (Datacolor International Spectraflash SF 600 Plus) on 15 g of ground (50-70 mesh) extruded samples which were uncoated. The data was recorded as L* (lightness), a* (redness) and b* (yellowness) values.

Maximum compression force (CF) was applied to measure a maximum force to indicate hardness of extruded samples by using a TA-XT2 i texture analyzer equipped with a compressing probe P_{50} (50 mm dia. cylinder aluminum). Instrument settings were as follow: pre-test speed; 5.0 mm/s test speed; 5.0 mm/s post-test speed; 10.0 mm/s compression distance; 50 % strain. 20 measurements were performed on each cylindrical shape extrude sample (11 ± 1.0 mm in diameter and

40 ± 3.0 mm length). Average of maximum compression force was recorded (N).

4. Sensory evaluation and acceptance test

A 20-member of experienced test panel was screened from researchers and assistant researchers of the Institute of Food Research and Product Development, Kasetsart University to evaluate the extruded samples. A 9-point hedonic scale (1 - extremely dislike to 9 - extremely like) was used to determine color, flavor, texture (crispiness) and overall acceptance. The panelists were requested to evaluate the samples according to their preference (Table 3). The SPSS software was applied for statistical analysis of ANOVA and DMRT test of difference between formula at 95% level of confidence. The evaluation was performed once on every other day and was totally conducted 5 times to complete 5 groups of samples. Samples from 16 rice-substituted formulas were divided into 4 groups. Group1, consisted of CR_1, CR_1', CR_2, CR_2'. Group 2 consisted of CR_3, CR'$_{3,}$ CR_4 and CR'$_4$. Group 3 consisted of CR_5, CR'5, CR_6 and CR'$_{6,}$ while Group 4 consisted of CR_7, CR'$_7$, CR_8, CR_8'. The highest score rated from each group were grouped into Group 5, where CR'$_0$ sample, the whole corn based snack was included. Final evaluation was conducted to select the most preferable formula for

Table 3 Sensory evaluation of corn based snacks substituted with broken rice (chicken flavored).

Group	Formula	Color	Flavor	Texture	Acceptance
1	CR_1	7.45^a	6.75^a	6.97^a	6.62^a
	CR'_1	7.45^a	6.92^a	7.00^a	6.85^a
	CR_2	7.40^a	6.77^a	6.85^a	6.80^a
	CR'_2	7.25^a	6.80^a	6.85^a	6.85^a
2	CR_3	7.30^a	6.85^a	6.90^a	6.85^a
	CR'_3	7.22^{ab}	6.87^a	7.00^a	6.95^a
	CR_4	7.10^b	6.70^a	6.80^a	6.80^a
	CR'_4	7.10^b	6.70^a	6.95^a	6.85^a
3	CR_5	7.10^a	7.02^a	7.00^a	7.00^a
	CR'_5	7.15^a	7.02^a	7.20^a	7.22^a
	CR_6	7.12^a	7.00^a	7.15^a	7.10^a
	CR'_6	7.17^a	6.90^a	7.05^a	6.90^a
4	CR_7	7.27^a	6.75^a	6.85^b	6.80^a
	CR'_7	7.12^a	6.62^a	6.72^b	6.75^a
	CR_8	7.00^a	6.60^a	6.92^{ab}	6.82^a
	CR'_8	7.02^a	6.70^a	7.22^a	6.95^a
5	CR'_0	7.25^b	6.67^b	6.65^b	6.62^b
	CR'_1	7.65^a	6.97^{ab}	6.75^{ab}	6.90^{ab}
	CR'_3	7.55^{ab}	6.87^{ab}	6.80^{ab}	7.00^a
	CR'_5	7.50^{ab}	7.05^a	7.05^a	7.15^a
	CR'_8	6.85^c	6.97^{ab}	7.02^a	7.02^a

In a column, means with the same letter are not significantly difference at $P \leq 0.05$

further production.

RESULTS AND DISCUSSIONS

The development of a basic formula for a standard corn based snack

As a favorable quality of extruded snack are generally specified as having a texture of crispy, clean eating, and most importantly, a light and puffy texture.

The puffing of direct expanded snack is created by heating the ingredients to the temperature above 100 C. The dough mixtures then become completely gelatinized but remains a liquid because of being under an internal pressure of the extruder. During the operation, starch becomes completely gelatinized while the entrapped water becomes superheated. Subsequently, as the extrudate exits the extruder through the die, the superheated water is exposed to the external atmospheric pressure. The steam vaporizes from water during this rapid pressure loss, thus, causes stretching and expansion of the starch matrix that grants the products a low density and light texture. Consequently, as the temperature is decreasing, the expanded structure of the extruded product becomes stable. Accordingly, puffiness of snacks is related to the evaporation of the superheated water in the gel, which is due to the pressure difference between inside and outside the barrel, and the size and number of generating gas bubbles.

The texture fineness in snack is manipulated by nucleating agent. Calcium carbonate, for example, provide surfaces at which gas bubbles may form during the release of water vapor (Guy, 1994). The appropriate amount of nucleating agent offers an optimum number and good distribution of the gas bubbles, therefore, offering a fine structure. Apart from nucleating agents, soybean oil is reported to be beneficial for facilitate the process and improve eating quality. Guy (1994) stated that 0.5-1.0% of soybean oil offerred smoothness to the low moisture dough (< 25% wwb) processed in high temperature and high pressure extrusion. It was found to improve eating quality by intervening between starch granules and protein matrix, thus, decreased the hardness.

C_6 formula with 93% corn-grit, 1%, calcium carbonate, 2% soybean oil, 3% sugar and 1% mixture of vitamins and minerals (Table 1) was selected as a basic formula for producing a standard corn-grit based snack. The highest expansion ratio of 3.90 was in a range reported for a low protein cereal based snack (3.06-3.83, Mohamed, 1990 and 4.03± 0.2, Boonyasirikool *et al*., 1996). Moreover, 70 g/L bulk density was in a satisfactory range of 50-160 g/L (Moore, 1994), 59 ± 10 g/L (Boonyasirikool *et al*., 1996) reported for a direct expanded snack. Despite that samples from formula C_1-C_5 were all achieving a favorable expansion ratio and bulk density, C_6 formula was selected due to the most preferable textural characteristics. Since hard texture snack was possibly not preferable among Thai consumers, C_6 samples exhibiting the lowest maximum compression force (69.2 N) complimentarily with the highest expansion ratio (3.90) were implying a good puffing with light texture. In spite of the fact that high puffing is a good, the thickness of the air cell wall and the air cell's distribution are considered. It is preferable that the cell wall's thickness should be minimal and the air cells are distributed evenly. It was confirmed from a microscopic examination (not illustrated) that the extruded samples from C_6 formula were displaying numbers of air cells with a slightly larger size compared to samples from C_1-C_5. Moreover, the distribution was found considerable evenly. Soybean oil was observed to locate suitably between the particles of starch and protein, therefore, promoting an optimum puffing and crispiness. Thus, it was concluded that C_6 formula could offer a good texture corn based snack.

For the formula added with 1 % soybean oil, it was discovered that increased percentage to calcium carbonate from 1 % (C_5) to either 2 % (C_4) or 3 % (C_2) resulted in an increase a number of smaller air cells, accompanied with lower expansion ratio, higher bulk density and higher compression force. It was evident that decreased expansion ratio from 3.75 to 3.45 and 3.33 together with increased maximum compression force from 79.3 N to 98.7 and 112.1 N as well as the bulk density from 71.8 to 73.0 and 73.1 g/L detected as $CaCO_3$ was increasing simultaneously. A dense biscuit like texture in the extruded samples with surface cracking were visible.

The increased amount of soybean oil from 1 % to 2% was discovered facilitating the uniformity in puffing and crispiness. Samples extruded from the formula with increased soybean oil to 2% in C_1, C_3 and C_6 showed higher expansion ratio (3.40, 3.48 and 3.90, respectively) and lower maximum compression force (96.5, 93.6, 69.2 N, respectively) compared to 1% of soybean oil in C_2, C_4 and C_5 which showed lower expansion ratio (3.33, 3.45 and 3.75 respectively) and higher maximum compression force (112.1, 98.7 and 79.3 N respectively). The results confirmed to what was stated by Guy (1994). In conclusion, C_6 was selected as a basic formula for producing a standard corn based snack and was recoded as CR'_0 in the following development of corn based snack substituted with broken rice.

Formulation of corn based snack substituted with broken rice

Formulation of direct expanded corn based snack substituted with broken rice and the results of sample examination are shown in Table 2. Broken rice were substituted from 10, 20, 30, 40, 50, 60, 70 and 80 % with and without 2% of soybean oil. The samples obtained from all formulas were examined and compared to the standard corn based snack (CR'_0). It was detected that the increase in substitution of broken rice from 10% to 80% resulted in the lower expansion ratio from 3.76 in CR'_1 to 3.52 in CR'_8. The same result also occurred in the formulas without 2 % soybean oil and the decrease in the expansion ratio was also detected (from 3.5 in CR_1 to 3.28 in CR_8).

The decreasing expansion ratio that occurred with the increasing percent broken rice substitution could due to the level of oil content. It was evident that an oil content in corn grit was 2.1% (Prabhavat *et al*., 1996) while an oil content in broken rice was 0.47% (by IFRPD Lab.). The increased substitution, thus, decreased the overall oil content in the formula. As it was noticed from a corn base breakfast cereal produced from twin screw extruder that the range of 2.0-3.0 % of oil content promoted an optimum expansion and improved eating quality (Boonyasirikool and Charunuch, 1997). Consequently, the higher amount of broken rice substitution containing only 0.47% oil, the more adverse effect on expansion would occur.

As bulk density was the inverse of expansion ratio, the corresponding result was evidenced. The increasing bulk density (from 75.48 g/L in CR'_1 to 91.50 g/L in CR'_8 and from 89.00 g/L in CR_1 to 103.90 g/L in CR_8) was obtained from the increase in broken rice substitution from 10 % to 80% either with or without 2% of soybean oil. Consequently, as the effect of decreasing oil content, the denser texture, also resulted in the increase of maximum compression force. It was detected that maximum compression force increased as broken rice was substituted at higher percentage (from 87.3 N in CR'_1 to 111.0 N. in CR'_8 and from 97.7 N. in CR_1 to 165.6 N. in CR_8) either with or without 2% of soybean oil in the formula.

The decrease in an expansion ratio and increase in bulk density and maximum compression force implied that substitution of broken rice in corn based extruded snack provided the crunchiness to the snack.

In addition, the changes would be beneficial for flavor coating process. The amount of the coated oil based flavoring could be minimized as the denser snack possesses a decreased volume, thus, leading to decreased surface area for coating for an individual piece. Consequently, upon consuming the snack, the proportion of protein to the coating oil increased.

Besides the textural results, the color values were determined. Corn based snack substitution of broken rice offered a higher lightness (L*) and lower yellowness (b*). Therefore, color of snacks could be noticed lighter in yellowness and would be advantageous in that more variety of coating flavors could be applicable.

With the presence of 2% soybean oil, the expansion ratio in CR'_1, CR'_2, CR'_3, CR'_4, CR'_5, CR'_6, CR'_7 and CR'_8 were higher than in the formulas without soybean oil; CR_1, CR_2, CR_3, CR_4, CR_5, CR_6, CR_7 and CR_8 respectively. On the other hand, bulk density and maximum compression force lowered with the presence of 2% soybean oil. For instance, samples from CR'_5 displayed the parameter of an expansion ratio, a bulk density and maximum compression force of 3.70, 76.60 g/L and 96.5 N. while CR_5 was detected at the value of 3.30, 101.70 g/L and 146.4 N, respectively. It was confirmed that addition of 2% soybean oil offered a more crispy texture instead of crunchy texture, therefore, it could imply that the samples would be preferable to Thai consumers.

It could be noticed that all the trial samples of corn based snack substituted with of broken rice ranged from 10% to 80% could achieve textural properties previously reported (Mohamed, 1990, Moore, 1994 and Boonyasirikool *et al.*, 1996). Furthermore, soybean oil below 3.0% was reported to improve eating quality (Boonyasirikool and Charunuch, 1997), therefore, the formula CR'_1-CR'_8 probably gain higher preference than CR_1-CR_8.

Sensory evaluation and acceptance

Table 3 demonstrates the score rated by the experienced panel. CR'_1, CR'_3, CR'_5 and CR'_8 gained the highest score in the testing group no. 1, 2, 3 and 4 respectively. They were subsequently evaluated in Group 5 with CR'_0, the standard corn based sample to achieve the final result. It was obvious that samples from CR'_5 formula with 50% broken rice substitution gained the highest preference score of 7.05, 7.05 and 7.15 in flavor, texture and acceptance respectively. Though preference scores of CR'_5 samples was significantly different from CR'_0 sample, however, there was no significant difference in preference scores between CR'_5 and CR'_1, or CR'_3, or CR'_8 at $P \leq 0.05$.

For the color preference, the score of 7.5 for CR'_5 samples was higher than score from CR'_0 samples (7.25), but was slightly lower than color preference score of CR'_1 (7.65) and CR'_3 samples (7.55), yet, they were not significantly different at $P \leq 0.05$. However, color preference score of CR'_5 was significantly higher than samples from CR'_8 formula (6.85) at $P \leq 0.05$. The increase in color preference score obtained from CR'_0 (standard formula) to10% substitution of broken rice in CR'_1 was obviously noticed as changes in color from yellowish orange to a lighter yellow. I it was complemented to CIE color value shown in table2 that L* increased and b* was decreased from CR'_0 to CR'_1.

The texture preference increased more in samples of CR'_1, CR'_3 and CR'_5 (6.75, 6.80 and 7.05, respectively) than in CR'_0 (6.65). The scores were corresponding to the increase in maximum compression force and bulk density displaying in table 2 where the increased substitution percentage of broken rice was found to promote higher bulk density and maximum compression force.

Nonetheless, the increased in color and

textural preference as the maximum substitution percentage was limited to 50% broken rice substitution. It was noticed that as the substitution exceeds 50%, the preference score decreased, in both color and texture.

Thus, it could be concluded that broken rice could be replaced by up to 50% of corn grit in the standard formula of corn based extruded snack. The 50% substitution of broken rice could succeed with the formula of 46.5% corn-grit, 46.5% broken rice, 1 % calcium carbonate, 2% soybean oil, 3 % refined sugar and 1% mixtures of vitamins and minerals. It was obvious that the 50% broken rice substituted formula offered a better texture and color than the former standard formula (whole corn grit). Hence, it would be profitable to advise the substitution of broken rice to the extrusion processors.

CONCLUSION

Corn based snack was formulated to achieve the textural properties i.e. light and crispy by optimizing the amount of calcium carbonate and soybean oil. Formulation was achieved with 93% corn-grit, 2% soybean oil, 1% calcium carbonate, 3% refined sugar and 1% mixture of vitamins and minerals and obtained the samples exhibiting an expansion ratio of 3.9, 70 g/L bulk density 69.2 N maximum compression force (C_6 in Table 1). The resulting formula was furtherly developed to improve texture, flavor and color to satisfy Thai consumer by substituting with broken rice. Study of broken rice substitution ranging from 10, 20, 30, 40, 50, 60, 70 and 80% was subsequently examined for textural properties and sensory evaluation. Samples from 50% broken rice substitution (CR'_5) which gained the highest preference scores showing 3.70 expansion ratio, 76.60 g/L bulk density and 96.5 N. maximum compression force and was scored higher in color, flavor, texture and acceptance than samples produced from whole corn-grit.

ACKNOWLEDGEMENTS

Financial support from The Institute of Food Research and Product Development (IFRPD) Kasetsart University is gratefully acknowledged.

LITERATURE CITED

Boonyasirikool, P., C. Charunuch and M. Phongpipatpong. 1996. Production of snack foods from mungbean by using laboratory twin screw extruder. Food Vol. 26 (1) : 14 – 33 (in Thai).

Boonyasirikool, P. and C. Charunuch, 1997. Production of corn-based breakfast cereal by twin screw extruder. Kasetsart J. (Nat. Sci.) 31 : 429-444 (in Thai).

Guy, R.C.E. 1994. Raw materials for extrusion cooking process, pp 52 – 72. *In* N.D. Frame (ed.) The Technology of Extrusion Cooking. Blackie Academic and Professional, an imprint of Chapman and Hall, Wester Cleddens Road, Bishopbriggs, Glasgow G64 2NZ, U.K.

Harper, J.M. 1981. Extrusion of Foods. Volume I. Food Extrusion. CRC Press, Inc., Boca Raton, Florida. 212 p.

Kosayothin, A. 1996. Snack Market in 2000: A Perspectives from Pepsi Co's Food Mogul. Tarnsettakit : 22 – 24 May, 16 (999) : 54 (in Thai).

Matz, S.A. 1984. Snack Food Technology. 2nd ed. AVI publishing co. Westport, Connecticut. 415 p.

Miller, R.C. 1988. Continuous cooking of breakfast cereal. Cereal Foods World. 33 : 284 – 291.

Mohamed, S. 1990. Factors affecting extrusion characteristic of expanded starch-based product, J. Fd. Proc. and Preser. 14 : 437 – 452.

Moore, G. 1994. Snack Food Extrusion, pp 110 –

143. *In* N.D. Frame (ed.) The Technology of Extrusion Cooking. Blackie Academic and Professional, an imprint of Chapman and Hall, Wester Cleddens Road, Bishopbriggs, Glasgow G 64 2NZ, U.K.

Pongsawatmanit, R. and P. Boonyasirikool. 1998. A Study on the Optimum Properties of Nonwaxy Rice and Waxy Rice for the Development of Snack Foods Produced from Twin Screw Extruder. A Research Report submitted to National Research Council of Thailand. 27 p. (in Thai).

Prabhavat, S., P. Boonyasirikool and C. Charunuch. 1996. Study on the production of snacks from ricebean by twin screw extruder. Kasetsart J. (Nat. Sci.) 30 : 200-210 (in Thai).

Sinthavalai, S. 1984. Thai snack foods: Part I. Basic Information for Product Development. Department of Product Development, Faculty of Agro - Industry, Kasetsart University, Bangkok. 330 p.

Received date : 3/03/00
Accepted date : 28/06/00