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Effect of Protein Content and Extrusion Process on Sensory and Physical Properties of Extruded High-Protein, Glutinous Rice-Based Snack

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ABSTRACT

Development of high-protein glutinous rice-based snacks containing glutinous rice flour, soybean meal and vital wheat gluten was produced using a twin-screw extrusion process. A factorial design was employed to investigate the influence of feed protein content (20 and 30%), feed moisture (20%, 25%, and 30%) and barrel temperature (150 and 180°C) on the sensory and physical properties of extrudates. Descriptive analysis results showed that increasing of protein content significantly increased hardness, noise, and crispness intensity but less sticky mouth feel coating. Increasing feed moisture content resulted in increased final extrudate hardness, noise, crispness and brittleness but reduced sticky mouth coating and colour. Extrusion under high barrel temperature (180°C) reduced intensity of all sensory attributes except colour. For the colour parameters, the increasing of protein content or barrel temperature, or decreasing of feed moisture resulted in decreasing of L*, while a* and b* values were increased. The increase in protein and moisture content and decrease in barrel temperature resulting in increased breaking strength index.

Key words: glutinous rice, extruded snack, descriptive analysis, colour measurement

INTRODUCTION

Glutinous rice (*Oryza sativa var. glutinosa* or *Oryza glutinosa*) is the important raw material in the extrusion manufacture of baked or popped snacks because it expands readily and produces a more porous texture (Jomduang and Mihamed, 1994; Athapol *et al*., 1997). It becomes an attractive ingredient in the extrusion industry due to its bland taste, attractive white colour, and ease of digestion (Kadan *et al*., 2003). Milled glutinous rice possesses protein around 6-7 %. It has protein quality with a chemical score of 55-59. Lysine is the limiting amino acid. Thus, the addition of proteinaceous and the modification of amino acid profile of rice grain are important objectives to develop high nutritional rice based snack.

Descriptive sensory analysis is a technique which enables the perceived sensory differences between two or more samples. Furthermore it is useful to determine whether

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aspects such as changing a process variable or ingredient have significant effects on product sensory characters (Risvik *et al*., 1997). Therefore, the objective of this study was to investigate the effect of protein content, feed moisture and barrel temperature on sensory and physical properties of extrudates.

MATERIALS AND METHODS

Raw materials and preparation

Commercial polished glutinous rice grains, vital wheat gluten (Davis Trading Co. Ltd., New Zealand) and soybean meal (Oppenheimer New Zealand Ltd) were used as the key ingredients. The rice was milled and fractured by passing through 70 mesh sieve. The mixing formulations of rice, soybean meal and wheat gluten were determined using linear programming. The 20% protein formula contained 71% rice, 6% soy and 23 % wheat; and the 30% protein formula contained 54% rice, 15% soy and 31 % wheat. The mixtures were packed into polyethylene bags (thickness of 195 micron) and allowed to equilibrate overnight at 5°C. Prior to extrusion, the moisture content of each mixture was determined (AOAC, 1990).

Extrusion conditions

A Model BC21co-rotating Clextral twin-screw extruder with intermeshing screws (Clextral, Firminy Cedex, France) and 3 mm diameter circular die was used. The unit was operated at flow rate of 12 kg h^{-1} and 400 rpm screw speed. Temperature profile in the four barrel sections from the feed end were set at 30, 30, 70, and 100°C for all experiments. Barrel temperatures at barrel sections 5, 6, and 7 were held constant at either 150 or 180°C. The feed moisture content was varied at 20, 25 and 30 %. After extrusion, samples were cooled to room temperature and sealed in laminate foil pouch (polyethylene terephthalate, PET 12 micron/ aluminum, AL 7 micron/ linear low density polyethylene, LLDPE 80 micron), and then kept under -18°C for further analysis. The extrudates were dried at 65±2°C in a tray dryer until a final moisture content of 3-4 %, then cooled to room temperature and sealed in laminate foil pouch before testing.

Sensory evaluation

Descriptor and panel training

Ten panelists comprised mainly the staff and students of the Kasetsart Univesity, who had good experience in sensory evaluation of snack products. Descriptor generation sessions, assessors tasted a range of the snacks and freely generated terms to describe their attribute, which were then recorded by the panel leader. Once decided, definitions for each attribute were established by the panel leader using existing literature (Meilgaard *et al*., 1999; Murray, 2001) and comments from each session. Assessors amended or changed definitions as necessary and established the comparison frame (reference points) by rating each product, in further session. The attributes elicited and definitions are shown in Table 1. The training involved seven sessions which the panelists were familiarized with different attribute notes using reference samples and also trained for performing the quantitative descriptive analysis test (Stone and Sidel, 1993; Murray, 2001).

Descriptive sensory analysis

The method used of intensity scaling was the quantitative descriptive analysis method. The scorecard consisted of 15 cm quantitative descriptive analysis scale where as the point at 1.25 cm and 13.75 cm were anchored as ‘low’ (recognition threshold) and ‘high’ (saturation threshold), respectively. Testing was performed in a sensory laboratory with individual booth under fluorescent lighting equal to daylight. Five pieces of extruded snack sample, at room temperature (25 ± 2°C), was served in 6×10 cm plastic bag labeled with randomly assigned 3 digit numbers. Water was used as palate cleansing material in

Table 1 Descriptive vocabulary and standard reference intensity ratings used in descriptive tests.

Attribute	Definition		Reference samples
Colour	Yellow colour from Munsell book of colour varying from light to dark. The low end of the scale represents a light yellow colour and the high end represents the dark yellow colour.	2.0 6.0 10.0 15.0	5 Y 9/2 2.5 Y 8.5/6 2.5 Y 7/8 2.5 Y 5/6
Noise	Measure the level of noise by biting through the sample with incisor teeth	0.0 Sandwich bread 6.0 Wafer 10.0 Potato chips	Farmhouse 1/2 in. cube 1/3 piece, Bissin coffee wafers Thai president foods Co. 1 piece, Testo, Berli jucker Co.
Hardness	A texture sensation associated with solid and dense products which represents the force required to bite initially through a product. The lower end of the scale represents very soft samples and the upper end of the scale represents very hard samples.	2.5 Egg white 7.0 Frankfurter 9.5 Peanuts 14.5 Hard candy	Hard cooked, 1/2 in. cube Large, 1/2in.cube, cooked 5 min, CP Co. 1 nut, Tong garden Co. 1 pieces, one colour, Clorets hard candy, Cranbury Adams Ltd.
Crispness	Crispy products tend to be associated with high pitched sounds and are likely to melt in the mouth. The low end of scale represents samples low in crispness, the upper end of the scale represents very crispness samples.	2.0 Granola bar 5.0 Cracker 14.0 Corn flakes	Chewy chunk, 1/3 bar, Nature valley, USA 1 pieces, Rosy cracker, imperial general food industry Co. Ltd. 1 oz. Kellogg's corn flakes cereal
Brittleness	A texture sensation which describes how easily a snack product breaks, fractures or splinters in the mouth. The lower end represents samples which are not brittleness and the upper end of the scale represents very brittle samples.	1.0 Muffin 4.0 Crackers 10.0 Wafer 14.5 Hard candy	1/2 in cube, Big C bakery 1/2 in cube, Nabisco 1/2 in square, Bissin coffee wafer, Thai president Ltd. 1 piece, Clorets hard candy, Cranbury Adams (Thailand) Ltd.
Sticky mouth coating	A sensation which relates to extent to which the sample become sticky (or starchy) in the mouth and covers the teeth. The lower end represents samples are not sticky, the upper end represents samples are very sticky	1.0 Carrot 7.0 Cracker 15.0 mongo leather	Uncooked, fresh, unpeeled 1/2 in slice. 1 piece, Rosy crackers, Imperial general food industry Co., Ltd. Ruckthai food product Co.

between the samples. Sensory analysis of 12 samples of extruded sample was done in four sessions.

Physical analysis

The colour of extruded snacks was measured with a Minolta spectrophotometer CM-3500d equipped with a D65 illuminant. The average value of three measurements was reported. Color readings were displayed as L^* a^* b^* values where L^* represents lightness/darkness dimension. The positive and negative a^* value indicates redness and greenness, respectively, and b^* indicates yellowness for positive value and blueness for negative value.

Breaking strength of extrudate was determined using a texture analyzer TA-XT2 (Stable Micro Systems, Surrey, England), with a 500 N load cell and a Warner-Bratzler shear cell (1-mm thick blade)(Ilo *et al*., 1999; Onwulata *et al*., 2001). The extrudates were analyzed at a cross head speed of 0.2 mm/s. Twenty randomly collected samples of each extrudate were assayed for each treatment. Breaking strength index (BSI) was calculated using peak breaking force (N) divide by extrudate diameter (mm).

Experimental design and statistical analysis

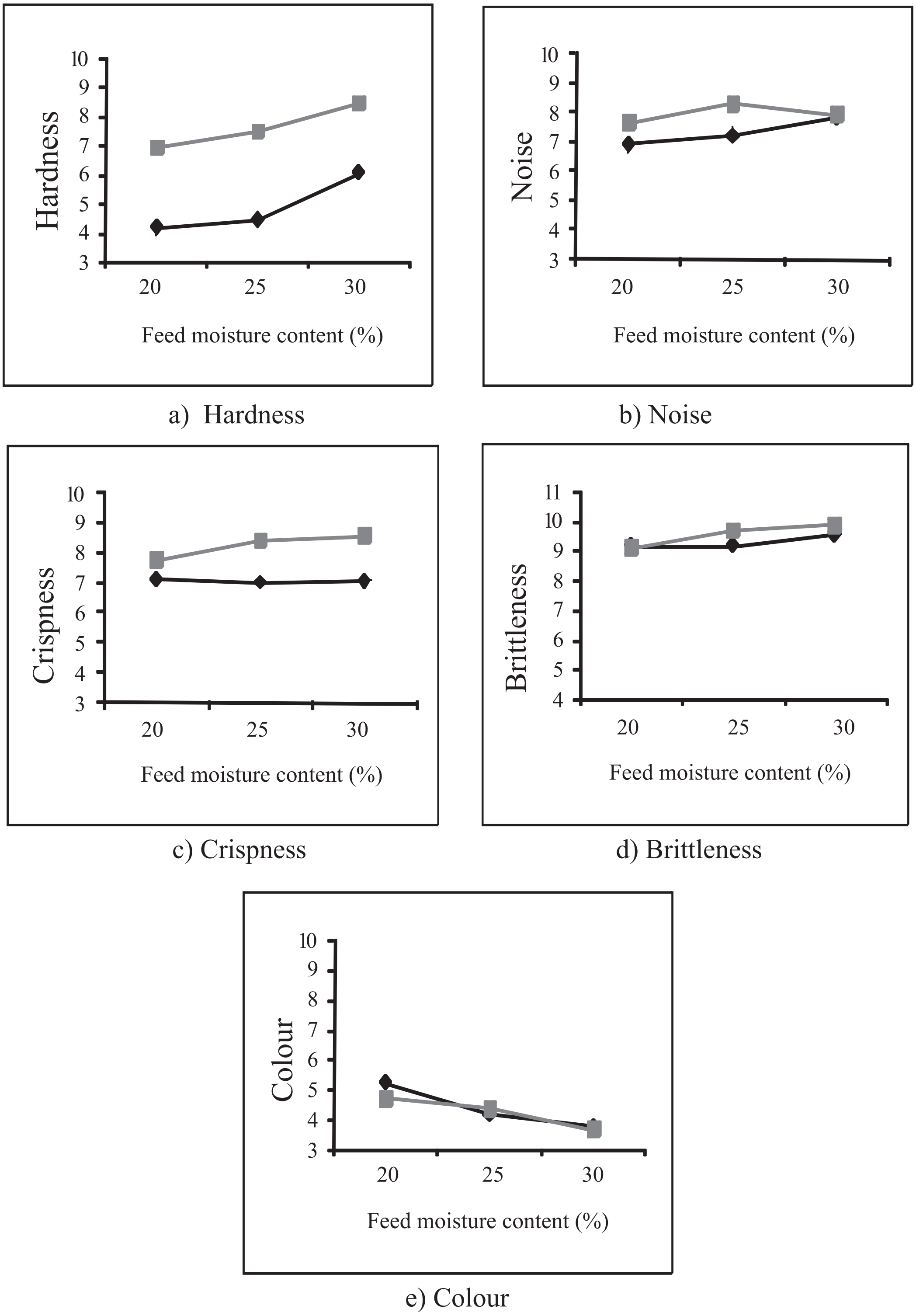
The 2x2x3 factorial design was employed to investigate the influence of protein content (20 and 30 %), feed moisture content (20, 25 and 30 %) and barrel temperature (150 and 180 °C) on the qualities of extrudates. Two replications of each extrusion condition were performed. The data were subjected to analysis of variance (ANOVA) using general linear model procedure, SPSS for Window Version 10.0 (SPSS Thailand Inc.) Means comparison was performed using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

The descriptive sensory evaluation results are shown in Table 2. An increase of protein content from 20 to 30%, resulted in significant ($P \leq 0.05$) increasing of hardness, crispness and noise intensity. These results were similar to the instrumental measurement, which breaking strength index increased as protein content increased (Table 2). Harper (1981) suggested that the presence of gluten protein was important factor related to hardness of extrudate. The wheat extrudate was a harder product compared to rice extrudate (Ding *et al*., 2005). In general, the characteristics of glutinous rice was sticky after cooked which the samples become sticky in the mouth and cover the teeth, thus addition of protein in formula resulted in decreasing of sticky mouth coating of products, which found in this study.

The feed moisture content significantly ($P \leq 0.05$) affected all descriptive attributes. There were significant ($P \leq 0.05$) interactions between protein content and feed moisture for all descriptive attributes, except sticky mouth coating (Figure 1). Increasing protein content at constant feed moisture content caused an increase in hardness, noise, crispness and brittleness but decrease colour intensity. However, it was observed that the noise intensity decreased when feed moisture content increasing from 25 to 30%. Increasing feed moisture content increased breaking strength index (Table 2). Faller and Heymann (1996) found that low moisture content (19%) potato extrudates were harder and crispier than high feed moisture (25%) samples.

Murray (2001) found that brittleness of maize based extrudates increased progressively with increased feed moisture content. Singh *et al.* (2007) noted that the hardness of rice-pea grits extrudates decreased with the increase in feed moisture content from 18 to 24 %. Results of colour intensity were similar to the instrumental colour measurement, which L^* increased as feed moisture increased while a* and b* value decreased (Table 2). These studies indicated that the decreased feed moisture resulted in the dark



a) Hardness b) Noise c) Crispness d) Brittleness e) Colour

Figure 1 Interaction effects of protein content and feed moisture on sensory attributes; the symbols correspond to the following protein contents-◆- 20 % protein , -■- 30 % protein.

Table 2 Mean of sensory attributes from descriptive analysis and physical properties of extruded snacks.

				Sensory analysis					Physical analysis			
Protein content (%)	Feed moisture (%)	Barrel temper-ature (°C)	Hard-ness	Noise	Crisp-ness	Brittle-ness	Sticky mouth coating	Colour	L*	a*	b*	Breaking strength index (N/mm)
20	20	150	4.8f	7.2d	7.3fg	9.2bc	9.3a	3.7e	81.4b	2.9fg	23.9g	1.0h
20	20	180	3.1h	6.6e	6.9g	9.1bc	8.8ab	6.6a	75.5j	6.0a	26.0c	0.6j
20	25	150	5.3f	7.5cd	7.7de	9.1bc	8.7ab	3.2fg	81.4a	2.5i	24.5f	1.3g
20	25	180	3.4h	7.0de	6.3h	9.0bc	8.5bc	5.0c	77.7h	4.6c	25.4d	0.7i
20	30	150	7.9c	8.5b	8.1bc	9.6ab	8.1bc	3.1g	81.1c	2.5i	24.1g	1.5f
20	30	180	4.2g	7.1d	6.1h	9.2bc	8.1bc	4.4d	79.9e	3.7e	25.0e	0.8i
30	20	150	7.7c	7.8c	8.3b	9.1bc	8.8ab	3.7e	80.1d	3.0f	25.4d	2.3c
30	20	180	5.9e	7.4cd	7.5ef	8.7c	7.5cd	5.6b	75.6i	5.9b	27.6a	1.7e
30	25	150	8.4b	8.7ab	9.1a	9.6ab	8.3bc	3.6ef	80.0d	2.7h	23.9g	2.7b
30	25	180	6.5d	7.7c	7.9de	9.2bc	7.2d	5.1c	77.7h	4.7c	26.4b	1.8d
30	30	150	10.2a	9.0a	9.3a	10.1a	8.2bc	3.4fg	79.4f	2.8g	24.8e	3.5a
30	30	180	6.8d	7.8c	8.0bc	9.4b	6.9d	4.1d	78.3g	4.1d	26.0	c1.8d

a-j means within the same column with different letters are significantly different (P≤0.05), *L**, index of lightness/ brightness ; *a**, index of redness/greenness; *b**, index of yellowness/blueness.

yellow colour of extrudates due to Millard reaction. Lawton *et al.* (1985) suggested that water in the extruder works as a heat sink/trap and lubricant and reduce shear strength. On the other hand, a low feed moisture lead to increase power requirements and surging (Conway and Anderson, 1973) and also resulted in excessive browning and stoppage of extrudate at die nozzle opening.

These results were contrasted with the effect of barrel temperature. Extrusion under high barrel temperature (180°C) decreased hardness, crispiness, brittleness, noise and sticky mouth coating, while increased colour intensity. The decrease of L* and the increase of a* and b* values were observed (Table 2). The breaking strength index of extrudate was also found to be strongly influenced by the barrel temperature (Table 2). Previous researches suggested that an increase in barrel temperature increased the degree of superheating of water in the extruder encouraging bubble formation and also decreased in melt viscosity, leading to reduce density and hardness of extrudate (Mercier and Feillet, 1975; Fletcher *et al.*, 1985).

The significant (P≤0.05) interaction between protein content and barrel temperature was observed for sticky mouth coating and colour attribute (Figure 2). Increasing barrel temperature at high protein content (30%) resulted in the sharp decrease of sticky mouth coating than that of low protein content (20%). Significant interaction between feed moisture and barrel temperature was also found in hardness, noise, crispness and colour (Figure 3). The increase of feed moisture and barrel temperature resulted in increase hardness, noise and crispness, but decreased colour intensity of extrudates. The highest hardness, noise and crispness of extrudate were obtained under the condition of 30 % feed moisture and 150°C, whereas this condition gave the lowest colour intensity. This result was the most likely caused by the formation of Maillard reaction products, which was promoted by condition with low moisture and high temperatures (Bredie *et al.*,

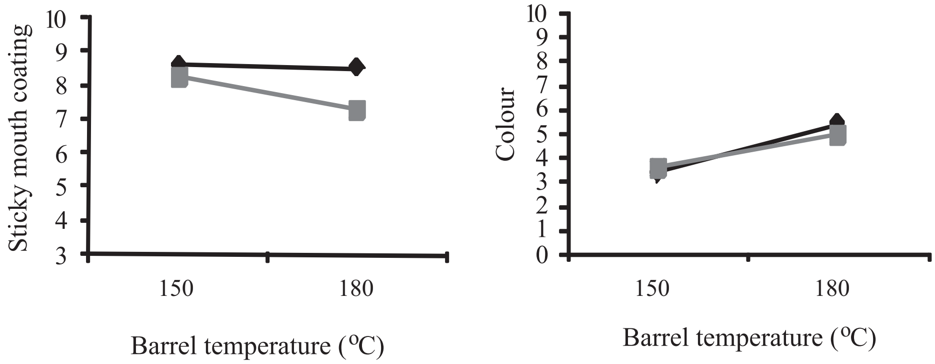


Figure 2 Interaction effects of protein content and barrel temperature on sensory attributes; the symbols correspond to the following protein contents -◆- 20 % protein, -■- 30 % protein.

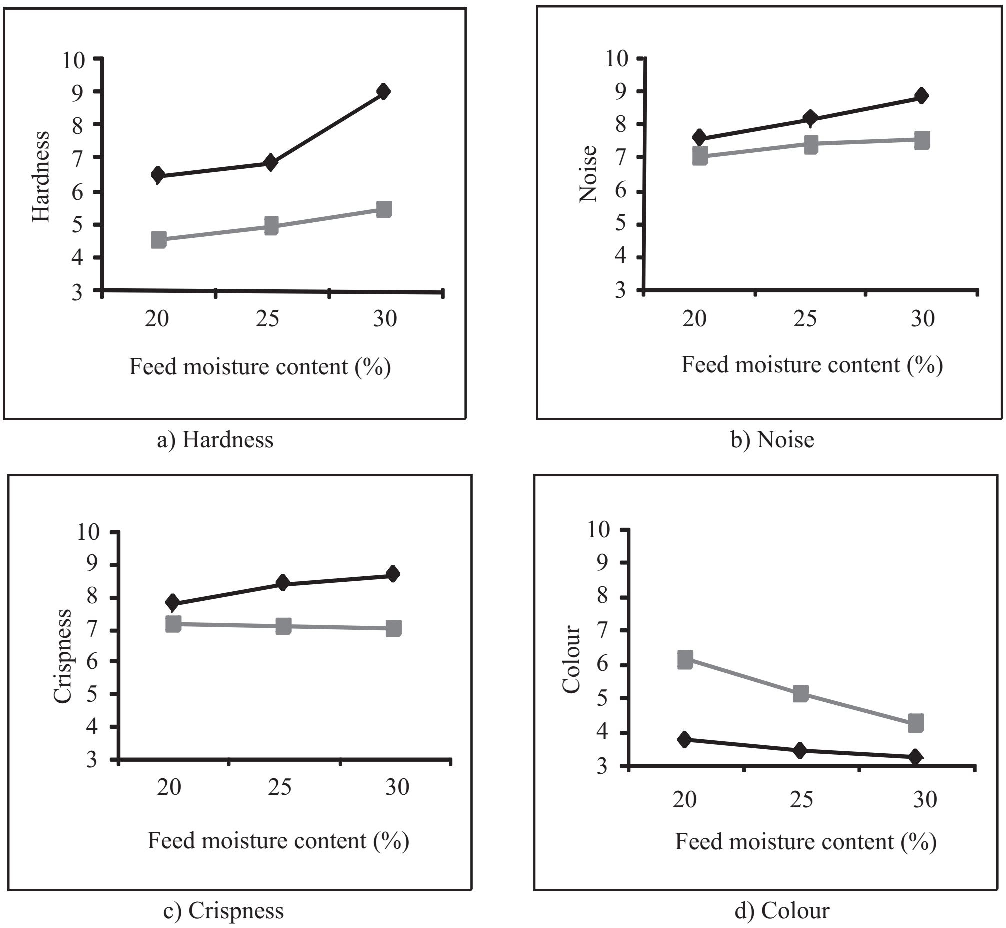


Figure 3 Interaction effects of feed moisture and barrel temperature on sensory attributes; the symbols correspond to the following barrel temperature -◆- 150 °C, -■- 180 °C.

1998). Ding *et al*. (2005) reported that the increment of barrel temperature and/or reduction of feed moisture resulted in decreasing of density, hardness and puncture energy of rice-based expanded snacks. Similar results were observed in rice-green gram blend (Bhattacharya, 1997), chestnut-rice flour blend (Sacchetti *et al*., 2004), and rice-pea grits blend (Sing *et al*., 2007).

CONCLUSION

The protein content, feed moisture content and barrel temperature significantly affected the sensory and physical properties of extrudates. The high protein snack extrudate had high hardness, crispness, noise and colour intensity. Addition of protein materials in the mixture resulted in reduced sticky mouth coating of extrudates. The extrudates obtained from the condition under low feed moisture content or high barrel temperature had low hardness, crispness, noise and brittle intensity but high sticky mouth coating and colour intensity. The colour intensity results were confirmed by the colour measurement, which the formulation contained 30 % protein, under the conditions of 20 % feed moisture, at 180 °C barrel temperature had lowest L* and highest a* and b*. The increase in moisture content in raw material and decrease in barrel temperature resulted in increased breaking strength index of extrudates.

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