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Effects of Pellet Moisture Content on the Physical Properties of Vacuum-puffed *Yukwa*

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Abstract

The effects of pellet moisture content on physical properties (expansion ratio, density and breaking strength) of vacuum-puffed *Yukwa* (non-oil puffed *Yukwa*) were investigated in this study. The *Yukwa* was made from the waxy rice steeped at 25 and 30°C for 3, 5 and 10 days with pellet drying times (6, 8 and 10.5 hr), respectively. As the drying time increased from 6 to 10.5 hr at 50°C, the highest value of pellet moisture content (29.4%) was found in the samples made from the steeped waxy rice at 25°C for 5 days after 6 hr drying, while the lowest value (16.3%) was found at 25°C for 3 days after 10.5 hr drying. Both redness and yellowness values of vacuum-puffed *Yukwa* increased as the drying time increased. The expansion ratio of *Yukwa* was greatly affected by drying time, ranging from 2.07 (26.8% pellet moisture content) to 7.01 (24.0% pellet moisture content). From the data, it was concluded that the pellet moisture content had a significant influence on the physical characteristics of vacuum-puffed *Yukwa*. With vacuum puffing condition of 3 min heating and 2 min puffing, the pellets with about 25% moisture content showed higher expansion ratio, and lower density and breaking strength.

Key words: pellet moisture content, physical properties, vacuum-puffed *Yukwa*

Introduction

Yukwa, a Korean traditional oil-puffed snack made of steeping waxy rice, has long been consumed as a popular snack due to its soft texture and unique taste (Chun et al., 2004). Korean people have traditionally prepared *Yukwa* for festive occasions such as birthdays and weddings as well as for ancestral memorial services (Kim et al., 2004). However, considerable oil uptake is observed in traditional *Yukwa* during frying. The oil content could cause deep-fried *Yukwa* to have a rather limited shelf life due to rancidity in the frying oil. Furthermore, edible oils used for food frying are subjected to the formation of compounds that are harmful to human health, such as enzyme inhibitors, vitamin destroyers, lipid oxidation products, gastrointestinal irritants and potential mutagens (Soriano et al., 2002).

Recently, many researchers are interested in making *Yukwa* with reduced or omitted oil content, as well as improved sensory characteristics. Lee et al. (2008) claims that the puffed *Yukwa* added with 10-20% Rubus coreanus Miquel extract by convection oven and microwave oven provides good physiological properties and reasonably high overall consumer acceptability. Moreover, microwave-puffed *Yukwa* was reported to have less expansion, but the same level of crispiness and hardness compared with oil puffed ones, while no difference in sensory characteristics of microwave puffed and oil puffed samples was found (Choi et al., 2000). On the other hand, Yang et al. (2008) reported that 1.0-1.5% of mugwort powder should be added to *Yukwa* baked in a far infrared ray electrical roaster in order to optimize physiological functions and keep overall acceptability reasonably high. In addition, there was a possibility to apply air puffing method for *Yukwa* making and its optimum temperature was around 250°C (Shin et al., 1990).

Yu & Ryu (2010) suggested that the optimum condition of vacuum puffing machine for the production of vacuum-puffed *Yukwa* was 120°C heating temperature, 4 min preheating time and 5 min puffing time. However, the influence of pellet manufacturing process on the characteristics of vacuum-puffed *Yukwa* has hardly investigated. Therefore, the objective of this study was to investigate the effects of pellet moisture content on the physical properties of vacuum-puffed *Yukwa*, and to optimize the manufacturing process of vacuum-puffed *Yukwa*.

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Materials and Methods

Materials

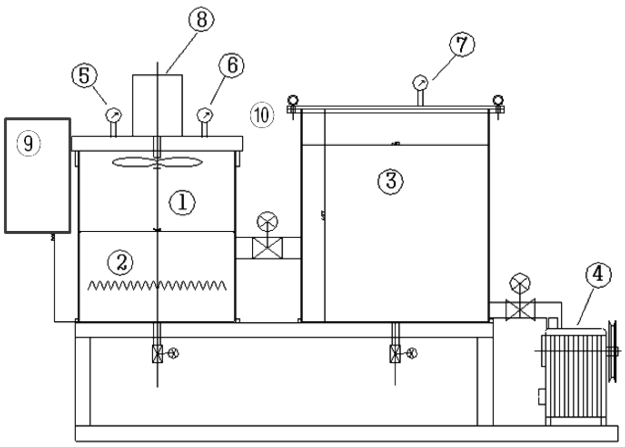
Waxy rice, obtained from a commercial source in Korea, was washed and steeped in water at 25 and 30°C for 3, 5 and 10 days. After draining for 12 hr over a sieve, the waxy rice was pulverized with a roll miller (Sinpoong ENG. Ltd., Daegu, Korea) for two times and stored in a refrigerator at 2°C until use.

Preparation of vacuum-puffed *Yukwa*

The milled waxy rice was steamed at 100°C for 60 min by using a steam cooker (Daechang stainless ENG. Ltd., Seoul, Korea), then the resulting dough was punched at mode 3 for 15 min with a KM 400 screw kneader (KENWOOD Ltd., Havant, UK). After cooling at 2°C for 3 hr, the dough was cut into small pieces with an average dimension of approximately 4 cm×1 cm×0.5 cm (length×width×thickness) and dried in a hot air oven at 50°C for 6, 8 and 10.5 hr. The dried pellets (called bandegi) were kept at 2°C for 2 days before puffing by vacuum puffing machine (Fig. 1). The vacuum puffing process was performed at 3 min heating time and 2 min puffing time.

Moisture content

The moisture content was performed using AOAC (1990). It was determined by the weight difference after drying at 135°C for 1 hr. Determinations were performed three times.



1	Heat chamber	6	Vacuum gage
2	Heater	7	Vacuum gage
3	Vacuum chamber	8	Fan motor
4	Vacuum pump	9	Control box
5	Pressure gage	10	Fan

Fig. 1. Assembly of vacuum puffing machine for vacuum-puffed *Yukwa*.

Expansion ratio

Expansion ratio was determined by the volume ratio of vacuum-puffed *Yukwa* and pellets. The volume of vacuum-puffed *Yukwa* and pellets was determined using a seed displacement method. Each assay was the mean of 10 repetitions.

$$ER = \frac{V_y}{V_p}$$

ER: Expansion ratio
Vy: Volume of vacuum-puffed *Yukwa*
Vp: Volume of pellet

Density

Density of expanded pellets was determined using the seed displacement method with millet seed. Density of the vacuum-puffed *Yukwa* was calculated by dividing its determined volume by the mass. Mean of 10 repetitions from each test was used to calculate the average value.

$$\rho_y = \frac{M}{M + M_m - M_1}\rho_m$$

ρ_y: Density of vacuum-puffed *Yukwa*
ρ_m: Density of millet
M: Mass of *Yukwa*
M_m: Mass of millet in cup
M_l: Mass of millet and *Yukwa* in cup

Breaking strength

The texture of vacuum-puffed *Yukwa* was evaluated using the Sun Rheometer (Compac-100 II, Sun Sci. Co., Tokyo, Japan). After setting the vacuum-puffed *Yukwa* on top of 2 cm wide platform, the sharp-edged probe (0.01 mm) was lowered to a speed of 120 mm/min with a 10-kg load cell. The breaking strength was calculated. The results were the average of 10 measurements.

$$F_{br} = \frac{F_m}{S}$$

F_{br}: Breaking strength
F_m: Maximum force during the cutting of vacuum-puffed *Yukwa*
S: Cross-sectional area of vacuum-puffed *Yukwa*

Color parameters

The darkest points of the surfaces of vacuum-puffed *Yukwa* were measured using a chromameter (CR-300, Minolta, Osaka, Japan). The color parameters L (black to white), a (redness to greenness), b (yellowness to blueness) were

Table 1. Analyses of variance for the effect of steeping conditions and drying time on the characteristics of vacuum-puffed *Yukwa*.

Parameters	Means square		
	Steeping temp (°C)	Steeping time (day)	Drying time (day)
Moisture content (%)	9.7682*	1.2125	99.6570***
Expansion ratio	3.7538	2.3058	5.2319*
Density (g/cm³)	0.0214**	0.0049	0.0104*
Breaking strength (N/m²)	9.48E+10	6.28E+10	9.26E+10
Color L	4.6107*	1.1994	7.2286***
Color a	10.5800*	0.3615	8.4029**
Color b	15.4568***	1.7727*	68.6006***

***Significant at $p < 0.01$; **Significant at $p < 0.05$; * Significant at $p < 0.1$.

recorded separately. Each assay was the mean of ten repetitions.

Statistical analysis

All statistics were analyzed using SAS version 9.1 (SAS Institute Inc., Cary, NC, USA). Analysis of variance (ANOVA) was performed by the General Linear Model procedure. Ducan's range test was used to detect significance of difference at $p < 0.5$.

Results and Discussion

Statistical analysis

The analysis of variance on physical properties of vacuum-puffed *Yukwa* is shown in Table 1. All of physical properties were significantly affected by drying time, except breaking strength. The steeping temperature had significant effects on pellet moisture content, density and color values. Drying time ($p < 0.01$) had a greater influence than the steeping temperature ($p < 0.1$) on pellet moisture content. However, the expansion ratio was only affected by drying time at a significance of $p < 0.1$. No significant effects of steeping conditions on expansion ratio of vacuum-puffed *Yukwa* were found.

Pellet moisture content

Pellet moisture content was significantly influenced by drying time ($p < 0.01$), and steeping temperature ($p < 0.1$), while no significant effect was observed for steeping time (Table 1). Increased drying time resulted in decreased pellet moisture content (Fig. 2). Moisture content at 25°C steeping temperature was decreased from 26.8 to 16.3% (3 days steeping time), 29.4 to 18.9% (5 days steeping time) and 24.4 to 16.8% (10 days steeping time) when the drying time increased from 6 to 10.5 hr. At 30°C steeping temperature, the pellet moisture content obtained from 10 days steeping time was slightly decreased from 26.2 to 26.1% in response to the increased drying time from 8 to 10.5 hr. A similar tendency on the effects of drying time to pellet moisture content was also reported (Kang & Ryu, 2002).

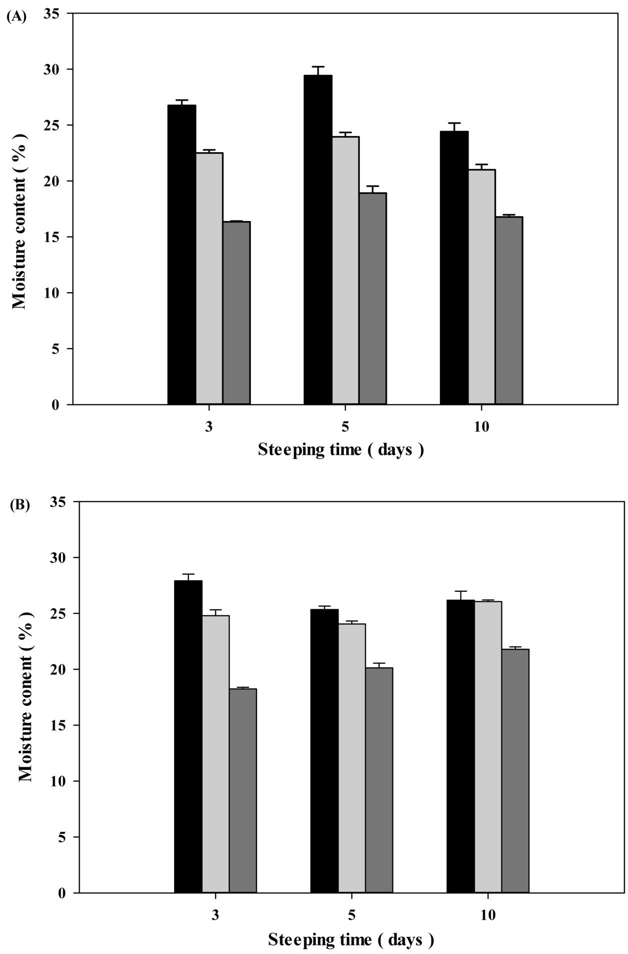


Fig. 2. The moisture content of pellet at steeping temperature of (A) 25°C and (B) 30°C (■: Pellet drying time for 6 hr; ■: Pellet drying time for 8 hr; ■: Pellet drying time for 10.5 hr).

After 6 hr drying time, the highest pellet moisture content (29.4%) was obtained at 25°C for 5 days steeping, while the

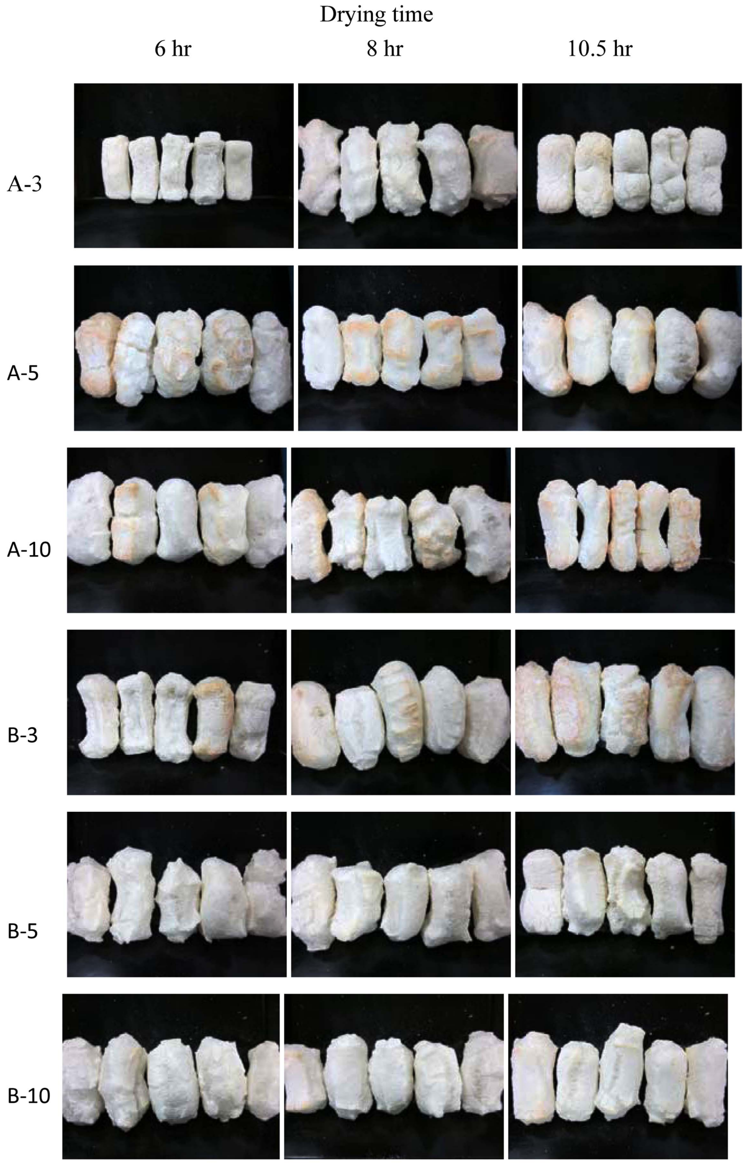


Fig. 3. Images of vacuum-puffed *Yukwa* depending on drying time (A-3, A-5 and A-10 as vacuum-puffed *Yukwa* from steeped waxy rice at 25°C for 3, 5 and 10 days, respectively; B-3, B-5 and B-10 as vacuum-puffed *Yukwa* from steeped waxy rice at 30°C for 3, 5 and 10 days, respectively).

lowest (24.4%) was found at 25°C for 10 days. The pellet moisture content ranged from 21.0 to 26.1% after 8 hr drying time. Pellets after 10.5 hr drying time had a higher moisture content of 20.1 and 21.8% for 5 and 10 days steeping at 30°C than the other steeping conditions, respectively.

Appearance and color of vacuum-puffed *Yukwa*

Fig. 3 showed the appearance of vacuum-puffed *Yukwa* that were made from pellets with different moisture contents. Irregular surface shrinkage was observed in the vacuum-puffed *Yukwa* compared to deep-fried *Yukwa*.

The values of the color parameters (L, a and b) affected by steeping conditions and drying time were shown in Table 2. Color values ranged from 68.54 to 79.63 for lightness, -1.72 to 5.45 for redness, and 7.73 to 21.11 for yellowness. The lightness of vacuum-puffed *Yukwa* from 10.5 hr drying time was not significantly different among steeping conditions of 25°C for 5 days, 25°C for 10 days and 30°C for 10 days. Redness and yellowness decreased with increasing drying time. The effect of drying time was significant for all measured color parameters as lightness and yellowness at $p < 0.01$ and redness at $p < 0.05$ (Table 1). In contrast, only

Table 2. Changes in the color values of vacuum-puffed *Yukwa* affected by different steeping conditions and drying time

Steeping temperature (°C)	Steeping time (days)	Color L			Color a			Color b		
		6[1)]	8	10.5	6	8	10.5	6	8	10.5
25	3	78.39±3.20$^{a2)}$	77.88±4.17^{bc}	79.17±3.81^{a}	+0.14±1.04^{bc}	-0.68±0.63^{b}	-0.90±0.37^{b}	+14.80±3.03^{cd}	+9.80±2.32^{c}	+7.73±2.43^{b}
	5	68.60±4.50^{b}	73.34±3.83^{cd}	72.96±4.15^{bc}	+5.45±2.38^{ab}	+1.18±1.94^{a}	+1.12±1.73^{a}	+20.28±3.27^{bc}	+15.22±4.79^{b}	+12.86±4.67^{b}
	10	72.49±2.93^{b}	73.68±4.03^{bcd}	73.03±4.22^{bc}	+3.97±1.64^{a}	+1.61±1.58^{a}	+0.47±1.30^{a}	+21.11±2.27^{ab}	+17.09±3.58^{a}	+14.32±3.86^{a}
30	3	68.54±3.65^{b}	70.74±4.22^{d}	71.58±5.12^{c}	+4.59±1.69^{ab}	+1.51±2.14^{a}	+0.68±1.59^{a}	+20.87±2.51^{a}	+16.93±3.30^{a}	+14.58±4.05^{a}
	5	77.74±3.67^{a}	78.74±3.60^{a}	79.63±3.21^{b}	-1.72±0.49^{c}	-1.71±0.37^{b}	-1.49±0.36^{c}	+12.98±2.47^{de}	+10.06±2.41^{bc}	+8.11±2.06^{c}
	10	76.11±3.75^{a}	77.84±3.68^{b}	77.73±3.53^{bc}	-0.69±0.89^{c}	-1.22±0.51^{b}	-1.39±0.40^{b}	+15.46±3.13^{e}	+9.36±2.84^{c}	+8.18±3.14^{b}

Values are Mean±SD of five repeats.
[1)]Pellet drying time (hr).
[2)]Values with different letters in the same rank are significantly different by multiple range test ($p < 0.05$).

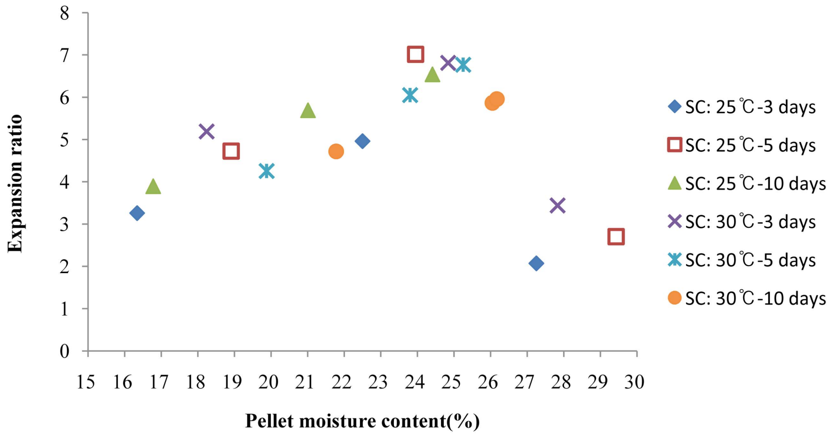


Fig. 4. Relationship between expansion ratio of vacuum-puffed *Yukwa* and pellet moisture (SC: steeping temperature and time).

yellowness was significantly influenced by steeping time, which was different from the significant effects of steeping period on color values of deep-fried *Yukwa* (Chun et al. 2002).

Relationship between pellet moisture content and expansion ratio

The relationship between pellet moisture content and expansion ratio of vacuum-puffed *Yukwa* was presented in Fig. 4. An increasing trend was observed in the expansion ratio of vacuum-puffed *Yukwa* as the pellet moisture content increased from 16.3 to 25.3% but decreased when the pellet moisture content over 26.0%. This was in disagreement with the findings (Kang & Ryu, 2002; Kim, 2003) that the highest expansion value of deep-fried *Yukwa* was obtained from bandegi with moisture contents of about 14-17%. The highest expansion ratio of vacuum-puffed was 7.01, obtained from pellet moisture content of 24.0%. This could be explained that a gelatinization of about 50% is acceptable for the manufacturing of expanded pellets because it allows air cells to form easily and then expand with successive buildup of vapor pressure without disrupting cell structure (Lee et al., 2000; Moraru & Kokini, 2003).

However, no significant effects of steeping conditions on expansion ratio of vacuum-puffed *Yukwa* were found as shown in Table 1. This was disagreed with the reports on deep-fried *Yukwa* that an increment in steeping time resulted in an increase in expansion ratio (Chun et al., 2002; Kang & Ryu, 2002; Cho et al., 2003).

Relationship between pellet moisture content and density

The relationship between pellet moisture content and density of vacuum-puffed *Yukwa* was exhibited in Fig. 5. As the pellet moisture content increased from 16.3 to 26.2%, density decreased from 0.20 to 0.09 g/cm^3. The density values of vacuum-puffed *Yukwa* obtained from the pellet moisture content of 26.8, 27.9, and 29.4% were 0.35, 0.18 and 0.32 g/cm^3, respectively. Similar phenomena about the effects of moisture content on density were reported by Kang & Ryu (2002). Increasing the steeping time of waxy rice had no

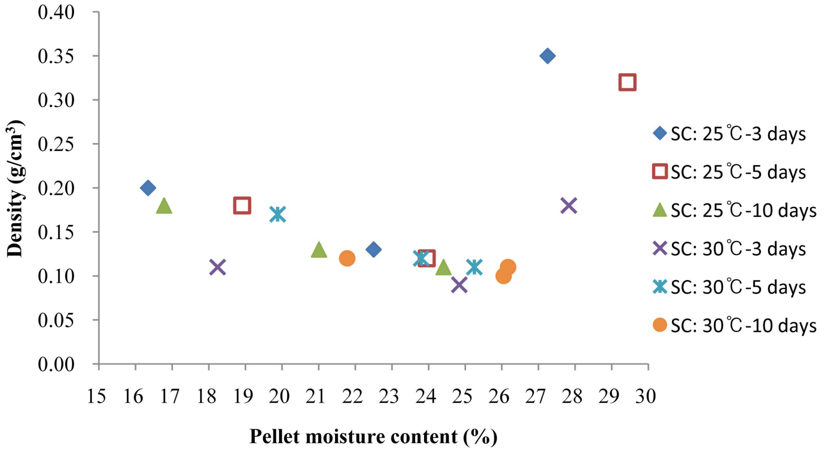


Fig. 5. Relationship between density of vacuum-puffed *Yukwa* and pellet moisture content. (SC: steeping temperature and time).

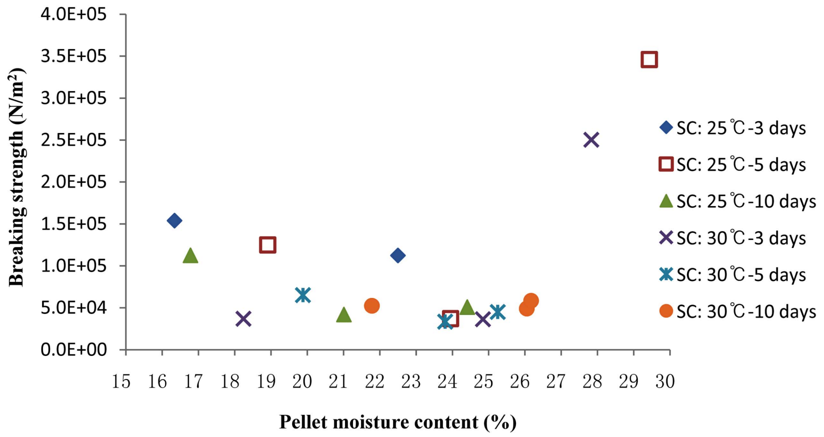


Fig. 6. Relationship between breaking strength of vacuum-puffed *Yukwa* and pellet moisture content. (SC: steeping temperature and time).

effects on the density of vacuum-puffed *Yukwa*. This was different from the findings of Chun et al. (2002) who observed significant effects of steeping time on density of deep-fried *Yukwa*.

Relationship between pellet moisture content and breaking strength

The breaking strength changes affected by the pellet moisture content are plotted in Fig. 6. The lowest breaking strength values of vacuum-puffed *Yukwa* were observed with pellet moisture content ranged from 24-26%. From the results described above, it can be indicated that breaking strength had a negative correlation with expansion ratio and a positive correlation with density. Martinez-Serna & Villota (1992) reported that products with a higher expansion formed bubbles of air with thin walls, with resulting low cutting forces. The texture of expanded products, particularly expanded snack foods, is one of the most important factors for industry and consumers (Limón-Valenzuela et al., 2010).

Conclusions

No significant influence of steeping period on the properties of vacuum-puffed *Yukwa* was found in this study. Steeping temperature of 30°C and 8 hr drying time appeared to be the optimized conditions for vacuum-puffed *Yukwa*. When the pellet moisture content was about 25%, vacuum-puffed *Yukwa* presented a higher expansion ratio, lower density and breaking strength. These results can give valuable information for the development of vacuum-puffed *Yukwa*.

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