Korean J. Food Preserv.
Vol. 14, No. 5. pp. 504-510, October 2007

사단법인 한국식품저장유통학회
THE KOREAN SOCIETY OF FOOD PRESERVATION

Physicochemical Properties of Rice Extrudate Added with Onion *Kimchi* Powder

Ittiporn Keawpeng · 강성구[1] · 박양균[†]
목포대학교 식품공학과 및 식품산업지역혁신센터, [1]순천대학교 식품과학부

양파김치 분말을 첨가한 쌀 압출팽화물의 이화학적 특성

Ittiporn Keawpeng, Seong-Koo Kang[1] and Yang-Kyun Park[†]
Department of Food Engineering and Food Industrial Innovation Center, Mokpo National University, Mokpo 534-729, Korea
[1]*School of Food Science, Sunchon National University, Sunchon 540-742, Korea*

Abstract

An extrusion process was used to make an onion kimchi snack from rice grit and onion kimchi powder, in an effort to enhance the nutritional value, flavor, and physicochemical properties of the extrudate. This study investigated optimum conditions (moisture content, barrel temperature, and the content of onion kimchi powder) for the production of high-quality rice extrudate products, and measured quality properties (water absorption index, texture, expansion ratio, and color) of rice extrudate to which onion kimchi powder had been added. Onion kimchi powder at 3%, 5%, 7%, and 10% (all w/w) was mixed with rice grit, and the mixture then extruded in a twin-screw extruder. The texture of onion kimchi snack became softer as onion kimchi powder level rose, and water absorption ability increased. The expansion ratio and the lightness of extrudates decreased with increases in onion kimchi powder levels. The maximum water absorption index and the minimum hardness were obtained with 10% onion kimchi powder. Rice extrudate with 10% onion kimchi powder was suitable for extrusion cooking and obtained the highest score for overall acceptability by sensory evaluation.

Key words : extrusion, rice snack, onion kimchi, physicochemical properties

Intoduction

Rice is one of the world's most important cereals for human consumption. In the densely populated countries of Asia, especially, east and southeast Asia, rice is the most important staple food. As much as 80% of the daily calory intake of people in these Asia countries is derived from rice(1). It is the principle food grain of Korea. However, the change of food intake of Korean people leads the decrease of rice consumption every year(2). In the oriental countries, rice is also consumed not only as the main food but also as a snack food processed by extrusion cooking(3). Rice is one kind of cereal have excellent expansion properties because of their high starch content and are well suited to thermal extrusion(4).

Onion is one of the most wildly used vegetables as edible plants in Korea. Several studies(5) have shown that onion contains very high level of flavonoids, especially, quercetin and its glycosides. It is the major sources of flavonoids in diets(6). They contain anti-inflammatory, anticholesterol, anticancer and antioxidant components. Various onion products such as pickles, beverages and snacks are on the markets(2). Also onion kimchi made with red pepper powder, garlic and ginger is the traditional fermented vegetable food in Korea. Onion kimchi is usually used for food in the area where onions are produced. It is made in small amounts at

[†]Corresponding author. E-mail : ykpark@mokpo.ac.kr,
Phone : 82-61-450-2422, Fax : 82-61-454-1521

homes and there are few commercial products.

Extrusion cooking has become one of the most popular technologies in food processing. It is low cost, high temperature short time process, used worldwide for processing of a number of food products(7, 8). It has been used increasingly in the production of food and food ingredients such as breakfast cereals, baby foods, and snacks(9).

This research was conducted to study the effect of some process variable on the physicochemical properties for the snack-like extruded products which obtained using an ingredient such as onion kimchi powder. The onion powder was shown to be the suitable for the extrusion cooking process only when mixed with rice grits because of its limited tendency to expand(10).

The objective of this study was to investigate the combined effects of extrusion temperature, mixture's moisture content and onion kimchi powder contents for the rice extrudate preparation, and the physicochemical and functional properties of the rice extrudate added with onion kimchi powder.

Materials and Methods

Materials

Rice was purchased from a local market in Muan, Korea (2006 harvested), and was grinded and then sieved with standard sieve to get particle size was less than 10 meshes (2.0 mm). Onion (*Allium cepa* L.) was purchased from the area of Muan (2006 harvested).

Onion kimchi powder preparation

The kimchi was processed based on the *"Yangpa-kimchi"* recipe(11). Previously, garlic and leek were chopped. Onion was cut into 4 pieces and soaked in 15% (w/v) brine for 30 min and then washed twice with fresh water following 30min drainage. The prepared ingredients were mixed well and then distributed evenly on the onion. The kimchi mixture was fermented at 10°C for 2 weeks in a polyethylene box.

The onion kimchi was dehydrated with conventional hot air dry oven at temperature of 60℃ for 12 hrs. The dehydrated onion kimchi was grinded to powder with grinder (Philips, HR1727, China) immediately. The onion kimchi powder stored at temperature lower than 5℃ until used. The preparation of onion kimchi powder is shown in Fig. 1.

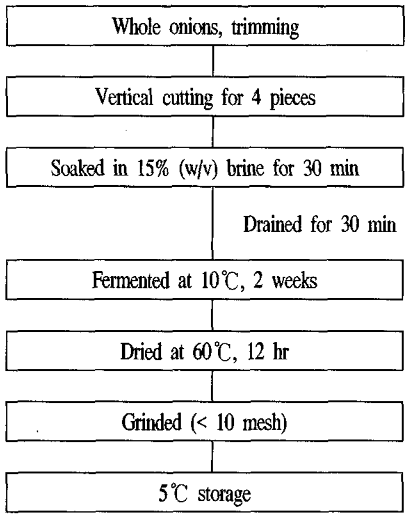

Fig. 1. Preparation of onion *kimchi* powder.

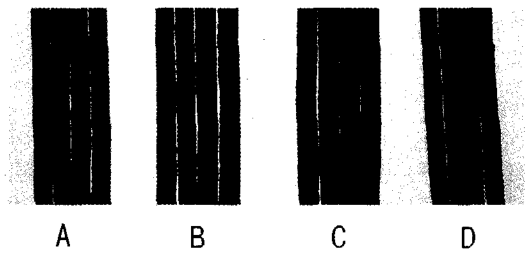

Fig. 2. Photographs of the rice extrudates added with different amounts of onion *kimchi* powder contents.

A : Onion kimchi 3%, B : Onion kimchi 5%, C : Onion kimchi 7%, D : Onion kimchi 10%.

Experimental design and conditions

The experimental design was designed with three variables; moisture content, barrel temperature and onion kimchi powder contents were taken as independent variables. Three extrusion processes were carried out for each combination of the two variables.

Moisture contents

The effect of moisture contents at 20%, 22%, 24% and 26% was determined on physical properties of the rice extrudate. Feed speed and screw speed were set at 130 g/min and 250 rpm, respectively. Barrel temperature was fixed at 100℃ in the third barrel (heating zone). The temperatures at the first and second barrels were set at 80℃ and 100℃, respectively.

Barrel temperatures

The effect of barrel temperature on physical properties of extrudate was determined by using rice grit blended with water. The moisture content of rice grit was fixed at 24%.

Feed speed and screw speed were set at 130 g/min and 250 rpm, respectively. Barrel temperature was varied at 100℃, 110℃, 120℃ and 130℃ in the third barrel (heating zone). The temperatures at the first and second barrels were set at 80℃ and 100℃, respectively.

Onion kimchi powder contents

The rice grit containing onion kimchi powder (3%, 5%, 7% and 10%) were extruded at 130 g/min feed speed. Temperature was set at 80℃ for the first barrel (pre-heating zone), 100℃ and 130℃ for the second barrel and third barrel (heating zone), respectively. Screw speed was set at 250 rpm. The moisture content of mixture was fixed at 24%.

Extrusion

Pilot extruder, co rotating twin-screw extruder (Incheon Mechanical Co., Model IHM 30, Korea) was employed for this study. The extruder was equipped with a draw plate which had a 7 mm diameter ring die. The heating system was in three stage with one pre-heating zone and two heating zone. The extrusion conditions were set at the optimum condition as described by Kim et al.(2). The feed speed was measured by volumetric feeder at a constantly screw speed. The feed rate was calculated as the weight of rice grit fed out from the feeder over 1 min, which was then converted from units into g/min. The feed speed was set at 130 g/min, screw speed was set at 250 rpm. Feed moisture level was fixed at 20%.

The samples were collected at a steady state of extrusion. Samples were dried in hot air oven, 100℃ for 5 hr or until the sample had less moisture content. The extrudates were kept at room temperature in the plastic bag until used.

Textural analysis

The texture of the extrudate was measured with the Rheometer (Sun Scientific Co., Compac-100 II, Japan) controlled by rheology data system (Sun Scientific Co., Japan) as described by Kim et al.(2). The machine was set at mode 21, test speed for 120 mm/s, rupture test distance 0.6 mm, maximum force 10 kg by using No. 9 adapter in this study.

Expansion properties

The radial expansion ratio or puffing rate of extrudate upon exiting from the die of extruder was determined by measuring the extrudate diameter by using digital vernier caliper (Mitutoyo, Digital caliper, USA). The expansion ratio was calculated by dividing the diameter of the extrudare by the diameter of the die nozzle. Ten measurements were made per treatment, samples were selected randomly.

Water absorption index

Water absorption index (WAI) was determined as described by Anderson et al.(9). Extrudate was ground using grinder (Philips, HR1727, China) and passed through a sieve (250 mesh). The 25 g of ground samples was suspended in distilled water (25 mL at 30℃) in a tarred 60 ml centrifuge tube. The suspension was stirred with a glass rod to break up any lumps, mixed for 30 min with a vortex mixer (Thermolyne, US/M-37600, USA), and centrifuged at 3,000g for 10 min (Hanil, Union 55R, Korea). The supernatant was carefully poured. The weight of gel in the centrifuge tube was measured. Three replicate measurements were recorded. The WAI were calculated by:

$$\text{Water absorption index (WAI)} = \frac{\text{Gel weight(g)}}{\text{Dry sample weight(g)}}$$

Colorimetry

The colors of ground extrudate (<250 mesh) was measured using a colorimeter (Hunter Associates Laboratory Inc., ColorQuest XE, USA). A HunterLab color space was used to measure the lightness (L, where L=0 for black; L=100 for white), the red/green (*+a* for red and *-a* for green) and the yellow/blue (*+b* for yellow and *-b* for blue). The colorimeter was calibrated using the white standard calibration plate, white tile standard (L=96.33, *a*=+0.09, *b*=+1.98) was used as reference (standard) color. Ten samples were done for each sample. The total color difference ($\triangle E$) was calculated using the following equation:

$$\triangle E = [(\triangle L)^2 + (\triangle a)^2 + (\triangle b)^2]^{1/2}$$

Sensory evaluations

A preliminary product selection was made in order to reduce the number of samples to be submitted to the panel which was made up by untrained judges. A final sensory evaluation was made by a group of 20 untrained judges (20~35 year old males and females) who were invited to evaluate hardness (qualitative rating), overall flavor and judgment (hedonic rating) of products. Seven point category scales were adopted and categories were rated from 1 (very low/dislike) to 7 (very high/like) in order to evaluate the statistical significance of the sensory results.

Statistical analysis

Experimental data was analyzed by analysis of the variance (ANOVA), generated for water absorption index, texture, expansion ratio, total color difference ($\triangle E$) and sensory evaluation of extrudates. Analysis of variance and Duncan's multiple range tests were performed by using the SPSS program to determine the differences among the extrudate. The level of significance was set at $P<0.05$.

Results and Discussion

Effects of moisture content on physical properties for rice extrudate

Quality of the extrudate depends on the extrusion process condition as well as the incorporated feed material(12,13). The physicochemical properties (WAI, texture, expansion properties and color) of the rice extrudate were investigated. The results were shown in Table 1.

Table 1. Effect of moisture contents of rice grit on water absorption index, texture, expansion ratio and color of extrudates

Sample		WAI[1)] (%)	Texture (g/cm^2)	Expansion ratio	Hunter color		
Barrel temp. (℃)	Moisture content (%)				L	*a*	*b*
100	20	705.18^a	52,385^a	1.76^a	88.40^a	-0.62^a	9.15^a
	22	714.04^b	52,942^a	1.71^a	88.65^a	-0.58^a	9.22^b
	24	721.52^c	55,293^b	1.64^b	89.12^b	-0.60^a	9.18^a
	26	732.46^d	58,234^c	1.58^c	90.17^c	-0.56^a	9.11^a

[1)]Water absorption index.
[a-d)]Means (n=10) with different superscripts within a column are significantly different ($p<0.05$) by Duncan's multiple range test.

The value of WAI of puffed snack products referred to the measurement of degree of starch gelatinization(14). Extrudate was shown the highest WAI value at 26% moisture content and lowest WAI value at 20% moisture content of extrudates. Gujska and Kahn(15) reported that moisture content of the material had a significant effect on WAI.

During the extrusion process, both of the elastic swell effect and bubble growth effect contribute to the structure change of starch(16). The degree of starch gelatinization and extrudate expansion was found to be negatively correlated to the feed moisture. The expansion of rice extrudates was 1.58 when the moisture content of rice grit was 26%. It seems the expansion ratio of extrudates significantly decreased with an adding in moisture content of rice grit. The water acts as a plasticizer to the starch-based material reducing its viscosity and the mechanical energy dissipation in the extruder and thus the extrudate becomes dense and bubble growth is compressed. Foods with lower moisture tend to be more viscous than those with higher moisture. Therefore, the pressure differential would be smaller for higher moisture foods, leading to a less expanded product. The low moisture content in feed may restrict flow of the material and increase shearing rate and residence time, which might increase the degree of gelatinization and expansion(12).

Feed moisture was found to have the most significant effect on extrudate hardness. The hardness of extrudate was increased when the moisture content of rice grit was increased. Ding et al.(17) and Badrie and Mellowes(18) reported that the hardness of extrudate increased as the feed moisture content increased. It might due to the reduced expansion caused by the increase in moisture content.

Colors of the rice extrudates were varied due to the changing in moisture content of blends. It became brighter when increased the moisture content of rice grit.

Effects of barrel temperature on physical properties for rice extrudate

The moisture content of rice grit was fixed at 24%, barrel temperatures were varied at 100℃, 110℃, 120℃ and 130℃ in the heating zone. The barrel temperatures for the first and second barrels were fixed at 80℃ and 100℃, respectively. Texture, WAI, expansion ratio and color of rice extrudate were shown in Table 2.

Table 2. Change of water absorption index, texture, expansion ratio and color of rice extrudate with various barrel temperatures

Sample		WAI[1)] (%)	Texture (g/cm^2)	Expansion ratio	Hunter color		
Moisture content (%)	Barrel temp. (℃)				L	*a*	*b*
24	100	645.31^a	56,421^a	1.61^a	91.48^a	-0.86^a	8.56^a
	110	652.45^b	54,864^b	1.66^b	89.37^b	-0.95^b	9.59^b
	120	659.72^c	51,974^c	1.72^c	88.38^c	-0.83^c	10.01^c
	130	667.64^d	49,736^d	1.79^d	88.19^c	-1.00^d	11.22^c

[1)]Water absorption index.
[a-d)]Means (n=10) with different superscripts within a column are significantly different ($p<0.05$) by Duncan's multiple range test.

Barrel temperature significantly affects to increase the WAI of rice extrudate when the temperature of barrel rise up. Barrel temperature at the 130℃ was shown the highest WAI value (667)and barrel temperature at the 100℃ was shown the lowest WAI value (645). WAI is a gelatinization index and it is generally agreed that barrel temperature exerts the greatest effect on the extrudate by promoting gelatinization. Lawton et al.(19) also found that soluble starch increased with increasing extrusion temperature. They found that WAI achieved a maximum value at higher than lower extrusion temperatures.

Barrel temperature also have an effect on the expansion ratio of rice extrudate. At the 100, 110, 120 and 130℃ of barrel temperature the expansion ratio of extrudates were 1.61, 1.66, 1.72 and 1.79, respectively. The expansion ratios were slightly increased. An increase in the barrel temperature will decrease the melt viscosity, which was confirmed by the report of Kadan et al.(20) that extrudate viscosity decreased with increased temperature. The reduced viscosity effect would favor the bubble growth during extrusion. Moreover, the degree of superheating of water in the extruder would increase at higher temperatures, also leading to greater expansion.

Barrel temperature was also found to have a significant effect on the hardness of extrudate. However, increasing temperature slightly increased the crispness of the extrudate. At 100℃ of barrel temperature the rice extrudate was shown the hardest in texture and slightly crisped until the temperature of barrel was raised up. During the extrusion process, the elastic swell effect and bubble growth effect both contribute to the structure change of starch(16). It is expected that increasing temperature would decreased melt viscosity, which favors the bubble growth and produce low density products with small and thin cells, thus increasing the crispness of extrudate.

The color of rice extrudates were shown a slightly darkness when barrel temperature increased. Color of the extruded products is mostly governed by the natural pigmentation of the raw materials; however, the processing variables, such as cooking temperature. The color of extrudate tends to turn slightly dark significantly on the barrel temperature. The increasing process temperature in extrusion cooking increased the rate of browning reactions which slightly change in colors.

Effect of onion kimchi powder content on physical properties for rice extrudate

The onion kimchi powder was blended with rice grit. Moisture content and barrel temperature were fixed at 24% and 130℃, respectively. The content of onion kimchi powder was varied at 3%, 5%, 7% and 10% (w/w). Texture, WAI, expansion ratio and color of the rice extrudate added with onion kimchi powder were shown in Table 3.

The expansion ratio of extrudates was significantly decreased with addition of onion kimchi powder. The expansion of extrudates was found to be the highest (1.89) at 3% and the lowest (1.69) at 10% of onion kimchi powder. Bhattacharya et al.(21) and Faubion and Hoseney(22) has been reported the relationship of extrudate expansions with the different materials. Decreasing the expansion of extrudates with addition of onion kimchi powder may be due to the higher protein and fiber and lower starch content of the feed material. Jones et al.(23) reported that an increasing of protein and fiber content in feed material resulted in a limit of expansion ratio.

Table 3. Change of water absorption index, texture, expansion ratio and color of rice extrudate added with various onion *kimchi* powder contents

Sample			WAI[1)] (%)	Texture (g/cm^2)	Expansion ratio	Hunter color			
Onion kimchi content (%)	Moisture content (%)	Barrel temp. (℃)				L	*a*	*b*	ΔE
0			667.14[a]	49,738[a]	1.94[a]	88.40[a]	-0.62[a]	9.15[a]	-
3			526.26[b]	41,988[b]	1.89[b]	76.72[b]	4.50[b]	32.65[b]	32.65[a]
5	24	130	542.75[c]	35,730[c]	1.86[c]	72.52[c]	6.25[c]	32.60[b]	31.23[b]
7			564.46[d]	32,774[d]	1.79[d]	70.76[d]	7.28[d]	35.41[c]	32.37[c]
10			578.59[e]	31,800[e]	1.69[e]	70.10[e]	7.05[e]	33.60[d]	35.22[d]

[1)]Water absorption index.

[a-e)]Means (n=10) with different superscripts within a column are significantly different ($p<0.05$) by Duncan's multiple range test.

The maximum WAI of the extrudates has been observed at 10% onion kimchi content. WAI was observed from 526 to 578 when the contents of onion kimchi powder were 3% and 10%, respectively. Gujska and Khan(15) reported the increasing in WAI by extrusion cooking of the high starch fraction compared to the low starch samples. Protein denaturation, starch gelatinization and swelling of the crude fiber, which occurred during extrusion, could all be responsible for the increased WAI of extrudates.

The hardness of extrudates was 41,988 g/cm^2 at 3% of onion kimchi. The hardness of extrudates was decreased to 31,800 g/cm^2 at 10% of onion kimchi.

The effect of onion kimchi content on the extrudate color, the response surfaces of L and *a* are referred to as Maillard reaction indices(24). The hunter color of extrudate which contained with 10% of onion kimchi was showed the greatest redness value, but the extrudate that contained with 3% onion kimchi was showed the lowest redness value. Rice extrudates containing onion kimchi powder had the color values of L 76.72~88.40, *a* 4.50~7.05 and *b* 32.65~33.62. There are many reactions during extrusion cooking that affects color of rice extrudates. The most common reactions are non-enzymatic browning reaction and pigment degradation. During extrusion cooking the L value decreased, whereas *a* and *b* values increased. Total color change in the response surface experiments of this study varied widely between 32.65 and 35.22. The color change of extrudate was most dependent on onion kimchi content and barrel temperature.

Sensory evaluation

Table 4 shows the mean values of sensory panel ratings of extrudates. The acceptance test of the rice extrudates evaluates the effect of an addition of onion kimchi powder on the quality of the onion kimchi snacks. Only the product extruded at 130℃ (heating zone), screw speed at 250 rpm, feed speed at 130 g/min and moisture content of 24% was considered acceptable by preliminary assessment performed by an acceptability test. The maximum overall acceptability was observed at 6.20 score on the rice extrudate blended with 10% onion kimchi, while minimum score was 3.90 on the rice extrudate blended with 3% onion kimchi. The sensory evaluation of the extrudates was different depending on the onion kimchi content. In the extrudate containing 10% of onion kimchi, the acceptance characteristics such as taste, texture and overall acceptability were gained the highest score. The acceptance in texture of rice extrudates showed significantly increased when added onion kimchi powder. The extrudates was slightly crisp and become soft in texture. The acceptance in appearance and color of extrudates with 3% of onion kimchi powder showed the lowest redness and highest expansion in its extrudates. The results in this study showed that there was significantly differences in the sensory evaluation among extrudates varied on onion kimchi contents.

Table 4. Sensory evaluation of the rice extrudates added with onion *kimchi* powder

Sample	Appearance	Color	Taste	Texture	Overall acceptability
A	5.50^{a*}	5.40^{a}	3.10^{a}	4.15^{a}	3.90^{a}
B	4.60^{a}	5.35^{a}	4.25^{b}	4.70^{b}	4.65^{b}
C	4.75^{ab}	4.95^{a}	4.80^{c}	5.00^{b}	5.40^{c}
D	4.70^{b}	4.85^{a}	6.35^{d}	6.20^{c}	6.20^{d}

$^{a-d)}$Means (n=30) with different superscripts within a column are significantly different ($p<0.05$) by Duncan's multiple range test.
*Sensory score scales ; 1 (extremely dislike or weak) ~ 7 (extremely like or strong)
A : Onion kimchi 3%, B : Onion kimchi 5%, C : Onion kimchi 7%, D : Onion kimchi 10%.

요 약

양파의 이용성 증대를 위해서 양파김치 분말을 첨가하여 풍미와 물리적 특성을 개선한 쌀 압출스낵의 제조조건에 따른 팽화물의 수분흡수율, 경도, 팽창률, 색도변화 및 관능검사 등의 품질특성을 조사하였다. 양파김치 분말 3~10%를 쌀가루에 첨가한 후 수분함량 20~26%로 조절하여 바렐온도 100~130℃, 스크루 속도 250 rpm에서 7 x 2 mm 압출구로 압출성형 한 다음 건조하여 양파김치 분말을 첨가한 쌀 압출팽화물을 제조하였다. 이들 중에서 양파김치 분말과 쌀가루 혼합물의 수분함량 24%, 바렐온도 130℃, 스크루 속도 250 rpm에서 제조한 압출성형물의 특성이 우수하였다. 쌀가루에 첨가한 양파김치 분말의 양이 증가할수록 압출물의 수분흡수율은 증가하였고, 경도와 팽창률은 감소하였으며 색차 ΔE 값은 증가하여 어두운 색깔을 보였다. 양파김치 분말 첨가량이 많은 10% 첨가구에서 수분흡수율은 가장 컸으나 경도는 가장 낮았다. 이같이 쌀 압출팽화물에 양파김치 분말을 첨가함으로써 팽화물의 물리적 특성을 개선하고 나아가 관능적 기호성을 향상시킬 수 있는 가능성을 보여 주었다.

Acknowledgement

This work was supported by Food Industrial Innovation Center (RIC) at Mokpo National University.

References

1. Bor, S. Luh. (1980) Rice production. AVI Publishing Co., Westport, Conneticut, USA
2. Kim, E.H., Kook, S.W., Jung, S.T. and Park, Y.K. (2005) Properties of rice extrudates added with the sea tangle powder. Korean J. Food Preserv., 12, 241-246
3. Mercier, C., Linko, P. and Harper, J.M. (1989) Extrusion cooking. AACC, St. Paul, Minnesota, USA
4. Singh, N., Sekhon, K.S. and Nagi, H.P.S. (1994) Effect of temperature on extrusion behaviour of sound and sprouted wheat flour. J. Food Sci. Technol., 31, 505-507
5. Knckt, P., Jarvinen, R., Reunanen, A. and Maatela, J. (1996) Flavonoid intake and coronary mortality in Finland. Brit. Med. J., 312, 478-481
6. Hertog, M.G.L, Hollman, P.C.H and Katan, M.B. (1992) Content of potentially anticarcinogenic flavonoids of 28 vegetables and 9 fruits. J. Agric. Food Chem., 40, 2379-2383

7. Frame, N.D. (1994) The technology of extrusion cooking. Blackie Academic and Professional, London, UK
8. Harper, J.M. (1981) Extrusion of starch and starch materials. In : Extrusion of food, Harper, J.M.(Editor), CRC Press, Boca Raton, Florida, USA
9. Anderson, R.A., Conway, H.F., Pfeifer, V.F. and Griffin, E.L. (1969) Gelatinization of corn grits by roll and extrusion cooking. Cereal Sci. Today, 14, 372-375
10. Kee, H.J., Ryu, G.H. and Park, Y.K. (2001) Physical properties of extruded snack made of dried onion and onion pomace. J. Korean Soc. Food Sci. Nutr., 30, 64-69
11. Cheigh, H.S. (2002) Kimchi culture and dietary life in Korea. Hyoil Publishing Co., Seoul, Korea
12. Chinnaswamy, R. and Hanna, M.A. (1988) Optimum extrusion cooking conditions for maximum expansion of corn starch. J. Food Sci., 53, 834-836
13. Ryu, G.H., Kim, B.S. and Mulvaney, S.J. (2004) Optimization of extrusion process for dairy ingredients fortification of cornmeal puffed via CO_2 gas injection. Food Sci. Biotechnol., 13, 219-244
14. Owsu-Ansah, J., Van de Voort, F.R. and Stanley, D.W. (1983) Physicochemical changes in cornstarch as function of extrusion variables. Cereal Chem., 60, 319-324
15. Gujska, E. and Khan, K. (1990) Effect of temperature on properties of extrudates from high starch fraction of navy, pinto and garbanzo beans. J. Food Sci., 55, 466-469
16. Panmanabhan, M. and Bhattachayrya, M. (1989) Extrudate expansion during extrusion cooking of foods. Cereal Foods World, 34, 945-949
17. Ding, Q.B., Ainsworth, P., Tucker, G. and Marson, H. (2005) The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-based expanded snacks. J. Food Eng., 66, 283-289
18. Badrie, N. and Mellowes, W.A. (1991) Texture and microstructure of cassava flour extrudate. J. Food Sci., 56, 1319-1322
19. Lawton, B.T., Henderson, G.A. and Derlatka, E.J. (1972) The effects of extruder variables on the gelatinization of corn starch. Canadian J. Chem. Eng., 50, 168-171
20. Kadan, R.S., Bryant, R.J. and Pepperman, A.B. (2003) Functional properties of extruded rice flours. J. Food Sci., 68, 1669-1672
21. Bhattacharya, M., Hanna, M.A. and Kaufman, R.E. (1986) Textural properties of extruded plant protein blend. J. Food Sci., 51, 436-443
22. Faubion, J.M. and Hoseney, R.C. (1982) High temperature and short time. Extrusion-cooking of wheat starch and flour. I Effect of moisture and flour type on extrudate properties. Cereal Chem., 59, 529-533
23. Jones, D., Chinnaswamy, R., Tan, Y. and Hanna, M. (2000) Physiochemical properties of ready-to-eat breakfast cereals. Cereal Foods World, 45, 164-168
24. Sacchetti, G., Pinnavaia, G.G., Guidolin, E. and Dalla, R.M. (2004) Effects of extrusion temperature and feed composition on the functional, physical and sensory properties of chestnut and rice flour-based snack-like products. Food Res. Int., 37, 527-534
25. Anderson, R.A., Conway, H.F., Pfeifer, V.F. and Griffin, E.L. (1969) Roll and extrusion cooking of grain sorghum grits. Cereal Sci. Today, 14, 372-377
26. Singh, B., Sekhon, K.S. and Singh, N. (2005) Effects of moisture, temperature and level of pea grits on extrusion behaviour and product characteristics of rice. Food Chem., 100, 198-202
27. Camire, M.E., Camire, A. and Krumhar, K. (1990) Chemical and nutritional changes in foods during extrusion. Crit. Rev. Food Sci. Nutr., 29, 35-57
28. Liu, Y., Hsieh, F., Heymann, H. and Huff, H.E. (2000) Effect of process conditions on the physical and sensory properties of extruded oatcorn puff. J. Food Sci., 65, 1253-1259
29. Lund, D. (1984) Influence of time, temperature, moisture, ingredients and processing conditions on starch gelatinization. Crit. Rev. Food Sci. Nutr., 20, 249-273

(접수 2007년 7월 10일, 채택 2007년 9월 21일)