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Characteristics in the components of the paprika by drying methods

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Abstract

The aim of this study was to investigate the characteristics of paprika dried by various methods. Moisture content of dried paprika was higher in vacuum freeze-dried red paprika (DRP) (11.85%) than in vacuum freeze-drying of osmotic dried red paprika in sugar (RPS), vacuum freeze-drying of osmotic dried red paprika in fructose (RPF) and vacuum freeze-drying of osmotic dried red paprika in corn syrup (RPCS). Carbohydrate content of DRP was the lowest among the dried groups, but fat, protein, and ash contents were the highest in DRP. The pH of paprika was the highest in RPF (5.34), while it was the lowest in DRP (5.05). Reducing sugar and sugar contents of RPF were 28.59 g/100 g and 5.03 °Brix, respectively, which are the highest level among the groups. All color values in inside of paprika were the highest in RPCS, while in outside of paprika, L value is the highest in RPCS, and the value of a, b were the highest in RPS. Regarding the texture characteristics of paprika, strongness, hardness, adhesiveness, chewiness and brittleness were the highest in RPS ($p<0.05$).

Key words : paprika, osmotic dried, vacuum freeze-dried, characteristics

Introduction

As lifespan has been extended due to the improvement of living standards in modern times, consumers are paying more attention to health and nutrition and the preference for natural foods and vegetarian diet is increasing (1). These changes have resulted in more physical strength and better nutrition. However the incidence of various diseases inducing cancer is still on the rise, of which important cause is known to be resulted from eating habits (2). The World Health Organization (WHO) recommends the consumption of fruits and vegetables rather than fish and meat, and indicates the intake of vegetables as an index of healthy eating habits. Neverthless according to the National Health Statistics of 2014, the intake of animal foods is high, while the intake of vegetables and fruits is relatively less than the recommended intake, resulting in high nutritional and health concerns (3).

Paprika (*Capsicum annuum* L.) is an annual plant of solanaceae and chili pepper species which originate from central America. It also called paprika, sweet pepper, pimiento, or bell pepper depending on the country. It is classified as sweet pepper according to the glossary of the Korean Society for Horticultural Science (4). The origin of paprika is Central America. In Korea, Gangwon-do and Gyeongsangnam-do account for 71% of the total production area, in which Gangwon area shows a noticeable increase and steadily increasing trend (5,6).

Paprika is strong in sweetness and rich in vitamin C without any spicy taste. It has varied colors such as green, yellow, and orange, and is mainly used as on ingredient for salads and stir-fry (7). As a warm-season crop, paprika is very sensitive to low temperatures. It is reported that according to the varieties, low-temperature disorders including accelerated aging, increase in softening of pulp, depression, maturity degradation and wrinkles are observed within the range of 0-10℃, accomparying with secondary infection of fungus

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known as a spotty rot (8).

During the storage of paprika, microbial action and decomposition are reported to cause the loss of nutrients that are important to taste, flavor and health as well as to its original vivid colors.

Generally hydrothermal treatment and low temperature storage, chemical treatment (9), high pressure CO_2 treatment (10). Other special pretreatment methods and management methods have been rarely studied (11).

Studies on the use of paprika have been performed on steamed rice cake (12), paprika juice (13), noodles with paprika powder (14), rice wine with paprika juice (15). the application as is powder through drying, a spice through juicing or as an additive material (16,17).

The advantage of natural and vegetarian foods is that most of them can be consmmed fresh without cooking. However, negligence in the production and distribution process can lead to decline in marketability (18). In order to solve these problems, studies on increasing the quality of the production and storage of paprika have been mainly carried out in Korea (19).

Osmotic drying developed by Ponting et al. is a drying method that uses the osmotic effect by using salt or saccharides (20). It is a drying method that can lower the loss of flavor and taste due to heat, prevent discoloration and remove the sourness of fruit, and enhance palatability by improving sweetness (21). In order to obtain good quality and shorten the drying time when drying fruits and vegetables, osmotic drying is widely used as a pretreatment method before conventional drying methods such as hot air drying, vacuum drying and freeze drying (22,23).

Therefore, the objectives of this study is to investigate the characteristics of red paprika such as general ingredients, physical properties, and functional components of paprika products dried by the combination of osmotic drying and vacuum freeze drying, and to present the possibility of processed foods using paprika to induce adivation of paprika of consuming it other than as raw.

Materials and Methods

Materials

In April 2016, fresh and bright red paprika (*Capsicum annuum* L.) was purchased from the National Agricultural Cooperative Federation. The test samples were washed with water and then dried on a shelf to remove water. The stalk ends and seeds were removed and the fruits were sliced into 2 cm×2 cm squares. Fructose (Krystar, Crystalline Fructose) was purchased from Krystar, and white sugar (white sage) and starch syrup (old syrup, Ottogi) were purchased from a general large-scale mart.

Preparation of dried paprika

For dried paprika, vacuum freeze-dried red paprika (DRP), vacuum freeze-drying of osmotic dried red paprika in sugar (RPS), vacuum freeze-drying of osmotic dried red paprika in fructose (RPF) and vacuum freeze-drying of osmotic dried red paprika in corn syrup (RPCS) were made.

For the osmotic dehydration, the materials were mixed well at the ratio shown in Table 1, then put in the zipper bag and left at room temperature for 24 h, with overturning and mixing every hour. After 24 h, the sugar water was removed through colander for 30 min. The dehydrated paprika was poured in a container containing 3 L of distilled water, stirred 10 times, and rinsed. After draining for 30 min again, paprika was spread on a table, dried for 1 h, and then vacuum freeze-dried for 7 days at -90℃ (FD8512, Ilshin, Dongducheon, Korea) after freezing for 24 h in a cryogenic freezer at -80℃ (MDF-U52V, Sanyo, Osaka, Japan).

Table 1. Formulation of dried red paprika

(g)

Sample[1)]	Components			
	Red paprika	Sugar	Fructose	Corn syrup
NRP	100	-	-	-
DRP	100	-	-	-
RPS	100	100	-	-
RPF	100	50	50	-
RPCS	100	50	-	50

[1)]NRP, natural red paprika; DRP, vacuum freeze-dried red paprika; RPS, vacuum freeze-drying of osmotic dried red paprika in sugar; RPF, vacuum freeze-drying of osmotic dried red paprika in sugar and fructose; RPCS, vacuum freeze-drying of osmotic dried red paprika in sugar and corn syrup.

Analysis of general components

The general components of paprika were analyzed according to AOAC method (24). That is, the moisture content was measured by the atmospheric pressure drying method and the crude protein content was measured by a Kjeldahl crude protein automatic analyzer (Foss Kjeltec™ 2300, FOSS, Hengenes, Sweden). The crude fat content was measured according to the Soxhlet method. The fixed quantity of crude ash was measured by the direct ash method. Carbohydrate content (%) was determined by subtracting moisture, crude protein, crude fat and crude ash content % from 100% of the total.

Measurement of titratable acidity and pH

To measure the acidity, 90 mL of distilled water was added to 10 g of paprika sample (24). The mixture was grinded using a homogenizer (AM-7, Nihonseiki Kaisha, Osaka, Japan) and filtered in a 100 mL volumetric flask with filter paper (Whatman No. 4). Then, 3 drops of 1% phenolphthalein (OCI Company Ltd., Seoul, Korea) solution were added to 20 mL of diluted sample solution and titrated with 0.1 N NaOH standard solution. The amount of base used to neutralize the solution was recoreded and acidity was calculated. The pH was measured by pH meter (HM-25R, TOA-DKK, Tokyo, Japan) using the sample solution made by pouring 90 mL of distilled water into 10 g of paprika sample, mixing and grinding it with homogenizer (AM-7, Nihonseiki Kaisha) and filtering it with filter paper (Whatman No. 4) in a 100 mL volumetric flask.

Hydration stability and moisture absorption rate

Hydration stability was measured by Lee et al. (25). About 55-66 g samples was taken as initial samples before each drying process. The dried sample was completely immersed in 1 L of boiling distilled water for 10 min for rehydration and taken out. The surface water was removed, and the weight is measured. This was conducted three times and expressed as an average value.

Moisture absorption rate was measured according to Lee et al. (25). About 4 to 5 g of dried samples were thoroughly immersed in 1 L of boiling distilled water for 10 min to be rehydrated and taken out. The surface water was removed and the weight is measured. This was repeated two more times and expressed as an average value.

Reducing sugar content and total sugar contents

The reducing sugar content was measured according to the Somogyi-Nelson method (26). For the sample solution, 50 mL of distilled water is added to 2 g of the sample, grinded with a hand blender (HR1607, Philips, Guangdong, China) and centrifuged at 3,000 rpm for 10 min using a high speed refrigerated centrifuge (VS-24SMTI, Vision, Seoul, Korea). Then, the supernatant was filtered through a filter paper (Whatman No. 4) in a 100 mL volumetric flask. After diluting this sample solution to the appropriate concentration, 0.5 mL of solution A with 1 mL of sample solution for each concentration at 25:1 is added and heated in boiling water for 20 min, and cooled. After adding 1 mL of solution C, spectrophotometer (U-2001, Hitachi, Tokyo, Japan) was used to measure the absorbance at 520 nm. The calibration curves were prepared with glucose to calculate the reducing sugar of paprika and expressed as the mean value of 3 repeated measurements.

For sugar content, 90 mL of distilled water is added to 10 g of sample, grinded with homogenizer (AM-7, Nihonseiki Kaisha), and filtered with filter paper (Whatman No. 4) in a 100 mL volumetric flask and then rectified. The sugar content of the solution was measured with a sugar meter (PAL-3, ATAGO, Tokyo, Japan).

Color value measurement

Color is a very important factor visually for consumers who consume the product and plays a pivotal role in stimulating preference. The color value was measured with a Chroma meter (CR-200, Minolta, Tokyo, Japan) and this was expressed as Hunter value L (lightness), a (redness), and b (yellowness). The inside of paprika and the outside of paprika were measured 6 times respectively, and the standard plate measured at this time was shown as a mean value by measuring repeatedly 6 times according to the usage of the equipment.

Measurement of physical properties

The physical properties of paprika were measured using a Sun rheometer (COMPAC-100 II, Sun Scientific, Tokyo, Japan). Under the measurement conditions, the test type is mode 21, distance 15 mm, plunger diameter 300%, adapter type number. 4, table speed 60 mm/m, and load cell (max) 2 kg. The strength, hardness, adhesiveness, cohesiveness, cohesiveness, springiness, chewiness, and brittleness were measured 10 times repeatedly and expressed as a mean value.

Statistical analysis

All experiments were repeated at least 3 times and expressed as mean±SD. One-way analysis of variance (ANOVA) was performed using the SPSS 23.0 statistical program (Chicago, IL, USA) to verify the significance level at $p<0.05$. The significant differences between the sample groups were analyzed by Duncan's multiple range test (28).

Results and Discussion

Changes in general components

Table 2 shows the results on general components of paprika dried by various methods. The moisture content of undried raw paprika was 92.86%. DRP paprika and paprika in the osmotic drying group with freeze drying were 11.85% and 6.94-7.57%, respectively. The decrease of moisture content in osmotic-combined dried samples seems to be due to the dehydration caused by osmostic process. According to the carbohydrate content of paprika, that of fresh paprika was the lowest at 6.47%, contrary to the water content, the content of osmotic dehydration group was the highest, 90.02-90.65% followed by 80.75% of DRP. RPCS showed the highest in carbohydrats content and the lowest in moisture content.. According to the crude protein content of paprika, DRP has the highest (1.71%) and RPS has the second highest content of 0.65%. Raw paprika, RPF, and RPCS had relatively low contents of 0.27-0.07%. The crude fat of paprika showed that DRP 0.56% was the highest and raw paprika has the lowest content of 0.09% and the osmotic drying group has 0.25-0.32%, which was between DRP and raw paprika. In the crude ash content, in paprika showed that the content of DRP (5.14%) was higher than that of osmotic drying groups which show the content of 1.60-2.02%. Park et al. (29) reported the quality and physiological activity of blueberries according to the drying method raw blueberry were moisture 86.52%, carbohydrate 11.51%, crude ash 0.20%, crude fat 0.20%, crude protein 1.64%, freeze dried blueberry moisture 17.32%, carbohydrate 77.02%, crude fat 0.71%, crude protein 3.84%. Compared with these reports, the effect of freeze-drying on the general components in current study tended to be similar.

Table 2. General components content of the dried red paprika by drying methods

(%)

Components	Samples[1)]				
	NRP	DRP	RPS	RPF	RPCS
Moisture	92.86±0.10[2)a3)]	11.85±1.66[b]	7.25±0.47[c]	7.57±1.25[c]	6.94±0.81[c]
Carbohydrate	6.47±0.19[c]	80.75±2.08[b]	90.02±0.84[a]	90.42±1.78[a]	90.65±1.17[a]
Crude protein	0.27±0.02[c]	1.71±0.04[a]	0.65±0.07[b]	0.16±0.06[d]	0.07±0.04[d]
Crude lipid	0.09±0.03[b]	0.56±0.17[a]	0.26±0.08[b]	0.25±0.20[b]	0.32±0.14[b]
Crude ash	0.31±0.05[d]	5.14±0.21[a]	1.81±0.23[bc]	1.60±0.27[c]	2.02±0.19[b]

1)NRP, natural red paprika; DRP, vacuum freeze-dried red paprika; RPS, vacuum freeze-drying of osmotic dried red paprika in sugar; RPF, vacuum freeze-drying of osmotic dried red paprika in sugar and fructose; RPCS, vacuum freeze-drying of osmotic dried red paprika in sugar and corn syrup.
2)All values are expressed as Mean±SD of triplicate determinations.
3)Different superscripts within the column are significantly different at $p<0.05$ by Duncan's multiple range test.

Changes in hydration stability and moisture absorption rate

Table 3 shows the results of hydration stability and moisture absorption rate of paprika according to the drying methods. The hydration stability of DRP (25.93%) showed the increase by 7% compared with that of osmotic dry group of 16.34-19.73%. This seems to be due to the fact that the leaching of the solution in osmotic dried samples was higher than that of DRP, which was only freeze-dried. In moisture absorption of paprika, like hydration stability, the osmotic drying group had a relatively lower moisture absorption rate than DRP; DRP showed, 220.12% followed by RPCS 157.18%, RPS 124.06%, RPF 111.47%. According to the study of Choi et al. (30) which showed the effect of the combination of osmotic drying and hot air drying on the quality of dried apple, the restorative power of the apple products subjected to osmotic dehydration decreased compared with the control group, and the restorative power was reported to decrease as the concentration of the immersion solution increased, which is a similar trend to this study.

Table 3. Rehydration rate and moisture absorption of the dried red paprika by drying methods

(%)

Samples[1)]	Rehydration rate	Moisture absorption
DRP	25.93±0.48[2)a3)]	220.12± 5.99[a]
RPS	17.25±0.29[c]	124.06± 3.72[c]
RPF	16.34±0.49[c]	111.47± 6.30[c]
RPCS	19.73±1.00[b]	157.18±13.02[b]

1)DRP, vacuum freeze-dried red paprika; RPS, vacuum freeze-drying of osmotic dried red paprika in sugar; RPF, vacuum freeze-drying of osmotic dried red paprika in sugar and fructose; RPCS, vacuum freeze-drying of osmotic dried red paprika in sugar and corn syrup.
2)All values are expressed as Mean±SD of triplicate determinations.
3)Different superscripts within the column are significantly different at $p<0.05$ by Duncan's multiple range test.

Changes in titratable acidity and pH

Table 4 shows the pH and acidity of paprika according to the drying methods. DRP showed the highest acidity (2.93%) and RPF showed the lowest value (1.73%). RPS and RPCS had the acidity of 2.72% and 2.22%, respectively, and the raw paprika showed the lowest acidity (0.80%). According to the results of pH of paprika, RPF showed the highest pH, 5.34 followed by RPS 5.31, RPCS 5.25, raw paprika 5.10, and DRP 5.05. Generally, paprika by drying had the value of about pH 5 and was slightly acidic.

The study of Moon (31) who studied the quality of *Cheongpomuk* (mung bean jelly) containing lotus leaf powder showed that pH and activity of freeze-dried lotus leaf powder for each region were different. In the effect of osmotic drying and vacuum infusion on the quality of apple Choi et al. (32) reported that the acidity of the osmotic dried apple has dropped more than twice compared with the control group; 151.2% in the control group to 61.4% in the osmotic dried group. This is because when the osmotic drying treatment is performed, a large amount of apple organic acid is eluted into the external sugar solution due to osmotic pressure, which is similar with the results of this study.

Table 4. Titratable acidity and pH of the dried red paprika by drying methods

Samples[1)]	Titratable acidity (%)	pH
NRP	0.80±0.09[2)e3)]	5.10±0.03[c]
DRP	2.93±0.08[a]	5.05±0.02[d]
RPS	2.72±0.03[b]	5.31±0.02[a]
RPF	1.73±0.08[d]	5.34±0.03[a]
RPCS	2.22±0.08[c]	5.25±0.02[b]

[1)]NRP, natural red paprika; DRP, vacuum freeze-dried red paprika; RPS, vacuum freeze-drying of osmotic dried red paprika in sugar; RPF, vacuum freeze-drying of osmotic dried red paprika in sugar and fructose; RPCS, vacuum freeze-drying of osmotic dried red paprika in sugar and corn syrup.
[2)]All values are expressed as Mean±SD of triplicate determinations.
[3)]Different superscripts within the column are significantly different at $p<0.05$ by Duncan's multiple range test.

Changes of reducing sugar and Brix

Table 5 shows the results of measuring reducing sugar and brix contents of paprika by drying methods. RPF showed the highest content of 28.59 g/100 g followed by DRP 22.26 g/100 g, RPS 20.76 g/100 g, RPCS 19.33 g/100 g, raw paprika 7.33 g/100 g. When comparing RPF 28.59 g/100 g with RPCS 19.33 g/100 g with the lowest content in the osmotic drying group, the difference of 9.26 g/100 g was shown. Sugar content raw paprika showed 0.62 °Brix and RPF showed the highest °Brix of 5.03 followed by RPS 4.73 °Brix, DRP 4.17 °Brix, RPCS 4.00 °Brix. In the study on the quality characteristics of domestic *Hanbarong jam* with fructo oligosaccharides and isomaltooligosaccharides, Choi et al. (33) reported that reducing sugar increased significantly as the addition of fructose increased, which was consistent with the results of this study.

Table 5. Reducing sugar and brix contents of the dried red paprika by drying methods

Samples[1)]	Reducing sugar (g/100 g)	°Brix
NRP	7.33±1.26[2)d3)]	0.62±0.03[e]
DRP	22.26±0.99[b]	4.17±0.06[c]
RPS	20.76±0.84[bc]	4.73±0.06[b]
RPF	28.59±1.05[a]	5.03±0.06[a]
RPCS	19.33±0.22[c]	4.00±0.10[d]

[1)]NRP, natural red paprika; DRP, vacuum freeze-dried red paprika; RPS, vacuum freeze-drying of osmotic dried red paprika in sugar; RPF, vacuum freeze-drying of osmotic dried red paprika in sugar and fructose; RPCS, vacuum freeze-drying of osmotic dried red paprika in sugar and corn syrup.
[2)]All values are expressed as Mean±SD of triplicate determinations.
[3)]Different superscripts within the column are significantly different at $p<0.05$ by Duncan's multiple range test.

Changes in color value

Table 6 shows the results of the color value of paprika by drying methods. In the inside of paprika, L values of RPCS, RPS and raw paprika were 61.55, 55.98 and 55.55, respectively, showing higher value than RPF 46.14 and DRP 31.28. Similarly, in the outside of paprika, L values of RPCS, RPS and raw paprika are 44.52, 40.39 and 39.71, respectively, which were higher than RPF 36.92 and DRP 30.16. The inside of paprika is generally brighter than the outside of paprika by showing higher L value.

In the inside of paprika, RPCS had the highest a value of 31.45 and DRP showed the lowest value of 23.70 and in the outside of paprika, RPS of 45.40 was the highest value and DRP of 23.10 was the lowest. Therefore, the outside of paprika is strong than the inside of paprika in redness.

In the inside of paprika, RPCS, RPS, raw paprika, RPF and DRP showed b values of 36.09, 33.94, 29.92, 22.48 and 12.07, respectively and in the outside, RPS, RPCS, RPCS,

Table 6. Hunter's color value of the dried red paprika by drying methods

Samples[1)]		Hunter color value		
		L	a	b
Inside	NRP	55.55±2.24[2)b3)]	29.48±3.03[a]	29.92±1.48[b]
	DRP	31.28±1.64[d]	23.70±2.72[b]	12.07±1.92[d]
	RPS	55.98±1.61[b]	30.93±1.82[a]	33.94±2.14[a]
	RPF	46.14±3.17[c]	31.03±2.53[a]	22.48±2.11[c]
	RPCS	61.55±2.02[a]	31.45±2.93[a]	36.09±2.77[a]
Outside	NRP	39.71±1.70[b]	33.04±1.83[c]	10.33±1.66[d]
	DRP	30.16±1.56[d]	23.10±2.52[d]	9.19±1.90[d]
	RPS	40.39±2.92[b]	45.40±1.67[a]	27.19±2.77[a]
	RPF	36.92±0.98[c]	37.86±1.56[b]	16.81±2.28[c]
	RPCS	44.52±2.46[a]	43.89±1.27[a]	22.78±3.75[b]

[1)]NRP, natural red paprika; DRP, vacuum freeze-dried red paprika; RPS, vacuum freeze-drying of osmotic dried red paprika in sugar; RPF, vacuum freeze-drying of osmotic dried red paprika in sugar and fructose; RPCS, vacuum freeze-drying of osmotic dried red paprika in sugar and corn syrup.
[2)]All values are expressed as Mean±SD of triplicate determinations.
[3)]Different superscripts within the column are significantly different at $p<0.05$ by Duncan's multiple range test.

raw paprika and DRP showed 27.19, 22.78, 16.81, 10.33 and 9.19, respectively, showing the higher yellowness in the inside of paprika. The color of dried paprika was clearer and brighter than that of only freeze-dried paprika during osmotic drying. Especially, RPCS had a higher value than RPS and RPF.

Kang et al. (34) reported that the color values of paprika were measured as L value of 30.75, a value of 23.27, b value of 11.38. Ha et al. (35) investigated the effect of shading method on growth and fruit characteristics when harvesting paprika during summer and reported that the color values of paprika outside were measured as L value of 36.4, a value of 34.3, b value of 18.9. Above study seems to be somewhat different from the results of this study but similar color values are shown.

When the color of raw paprika in this study was compared with the results of the studies of Kang et al. (34) and Ha et al. (35), differences were observed such as the variety, temperature, and cultivation area of paprika and temperature. Based on the color of paprika samples, which has also undergone osmotic dehydration is clearer and brighter. When developing processed foods of paprika, research and development considering this part will lead to products with better merchandise.

Changes in texture

Table 7 shows the results of texture measurement of paprika by drying methods. Strongness of RPS was the highest, 15.11 kg/cm^2 and that of raw paprika was 11.45 kg/cm^2. Strongness of RPF and RPCS was 6.19 kg/cm^2 and 6.94 kg/cm^2, respectively, showing the difference of more than twice compared to RPS. DRP showed the lowest strongness of 4.00 kg/cm^2.

Hardness of RPS and raw paprika was 12.28 kg/cm^2 and 8.44 kg/cm^2, respectively, showing higher value than the other groups. RPCS and RPF showed similar values, 4.37 kg/cm^2 and 4.44 kg/cm^2, respectively which were three times lower than RPS. DRP showed the lowest of 2.89 kg/cm^2.

As with strongness and hardness, RPS showed the highest adhesiveness of 358.00 g followed by RPCS (248.00 g). Adhesiveness of RPF and DRP were 135.00 g and 122.80 g, respectively, showing the values of about three times lower than RPS and about two times lower than RPCS. Raw paprika showed the lowest adhesiveness of 75.33. DRP showed the highest cohesiveness of 35.43%, and RPC and raw paprika showed high values of 34.63% and 33.27%, respectively. That of RPF was 27.18% and RPS showed the lowest value of 22.39%.

Four groups except RPS had similar springiness of 89.91-95.68% and RPS showed a value as low as 77.67%. Chewiness of RPS was the highest, 239.01 g and DRP showed the lowest value of 99.73 g. In brittleness, RPS and DRP had values of 189.98 g and 95.53 g, respectively.

Putting these results together, when paprika was freeze-dried, it is softened because hardness decreased. When osmotic drying is carried out together, RPF and RPCS showed a tendency of being soft because hardness decreased and stickiness increased due to sugar.

Conclusions

Carbohydrate content was high in dried group, but fat and crude ash content were high in DRP. Rehydration rate of vacuum infiltrated paprika was ranged from 16.34% to

Table 7. Texture characteristics of the dried red paprika by drying methods

Texture parameters	Samples[1)]				
	NRP	DRP	RPS	RPF	RPCS
Strongness (kg/cm^2)	11.45±0.70[2)b3)]	4.00±0.25^e	15.11±0.59^a	6.19±0.41^d	6.94±0.08^c
Hardness (kg/cm^2)	8.44±0.55^b	2.89±0.29^d	12.28±1.69^a	4.44±0.37^c	4.37±0.32^c
Adhesiveness (g)	75.33±11.15^d	122.80±16.99^c	358.00±27.54^a	135.00±16.60^c	248.00±26.70^b
Cohesiveness (%)	33.27±1.93^a	35.43±4.28^a	22.39±5.95^b	27.18±2.34^b	34.63±4.18^a
Springiness (%)	94.40±1.48^a	95.68±3.48^a	77.67±7.19^b	89.91±6.53^a	90.91±1.26^a
Chewiness (g)	119.84±13.07^c	99.73±5.86^c	239.01±37.47^a	118.99±13.39^c	169.85±13.60^b
Brittleness (g)	113.26±14.11^c	95.53±8.51^c	189.98±35.44^a	108.12±17.29^c	154.51±13.60^b

[1)]NRP, natural red paprika; DRP, vacuum freeze-dried red paprika; RPS, vacuum freeze-drying of osmotic dried red paprika in sugar; RPF, vacuum freeze-drying of osmotic dried red paprika in sugar and fructose; RPCS, vacuum freeze-drying of osmotic dried red paprika in sugar and corn syrup.
[2)]All values are expressed as Mean±SD of triplicate determinations.
[3)]Different superscripts within the column are significantly different at $p<0.05$ by Duncan's multiple range test.

19.73%, showed the highest in DRP (25.93%). Moisture reabsorption rate was the highest in DRP (220.12%). The pH of paprika was the highest in RPF (5.34), while it was the lowest in DRP (5.05). Reducing sugar content of RPF was as high as 28.59 g/100 g, and its sugar content was the highest as 5.03 °Brix. The L values of surfaces of inside and outside of paprika were all high in RPCS, and average a value was high outside, while average b value was high inside. Regarding the texture of paprika, strongness, hardness, adhesiveness, chewiness, and brittleness were the highest in RPS ($p<0.05$). Thus, this study may contribute to development of processed food and health functional food with dried paprika, promoting the activation of paprika market.

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