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POPPING EFFECT AND SENSORY EVALUATION OF CORN KERNELS TREATED WITH SALINE SOLUTION-SOAKING AND FREEZE-DRYING

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This study was designed to identify the optimal popping conditions for the making of popcorn with less salt and oil. A shorter soaking period in a low-salinity concentration was found to improve the popping rate. A combination of freeze-drying and heat blast-drying resulted in a lower moisture level in the kernels, leading to better popping than freeze-drying alone. The quantity variations in the oil used for popping suggested that the pre-treated kernels produced comparable popping rates despite requiring 13 to 30% less oil than the amount normally needed for kernels with no pre-treatment. However, there was no difference in terms of savory taste, sweet taste, salty taste, or preference. The results suggest that it is easier to produce a higher volume of popcorn by applying the proposed pre-treatment to the kernels, and that a 30% reduction in oil for the popping of pre-treated corns can yield a comparable popping volume to that of non-treated kernels.

Keywords: Popcorn, Popping effect, Kernel, Freeze-drying

INTRODUCTION

With the expansion of the popcorn market, consumers have been gaining easy access to various types of popcorn on the shelves of local supermarkets. As the taste of popcorn is based on the flavor of kernels salted after being popped in oil, the right amount of salt and oil is believed to contribute to the taste. But Kim and Choi (1995) reported that popcorn is one of consumers' favorite salty foods along with ramen, Korean-style side dishes, crackers, and potato chips, and suggested it is necessary to reduce the salinity to spice up popcorn.

Thanks to new campaign for healthy diet, low salinity and low calories have been buzz words. Lee *et al.* (2012) proposed the way to produce less salty popcorn by soaking kernels in saline and sugar solutions. They reported that kernels that were first soaked in a 13% saline solution for 12 hours then in a 0.1% sugar solution for five hours and that were then dried with a heat-blast dryer had a higher popping

rate and received higher ratings in popcorn sensory evaluations. In addition, the studies (Fedan *et al.*, 2006; Song *et al.*, 2010; Nguyen *et al.*, 2012; Sweley *et al.*, 2012; and Lee and Song, 2014) on new ways of spicing up and producing popcorn in order to minimize the trans fat and oxidation from the oil are being explored.

As Brunson (2015) indicated that the most important factor affecting sales was the volume, this study was designed to identify the optimal popping conditions for the popcorn companies and customers in making popcorn using less salt and oil with the application of different pre-treatment conditions through different salinity levels, soaking periods, and drying types, and through a sensory evaluation.

MATERIALS AND METHODS

Materials

This study used Speedy Pop Popping Corn (imported from the USA) and locally-purchased Saempyo Kosher salt.

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Pre-Treatment of Popcorn Kernels

The popcorn kernels were pre-treated by being soaked in a different saline solution prepared in a 25 °C shaking water bath (JSSB-30T, JSR) for different time periods. The kernels were then dried up for maintenance at a 11~12% moisture level with either a heat-blast dryer (the Liquip food dehydrator used at its highest operating level) or a freeze-dryer (an Ilshin Bondiro Freeze Dryer used at sub 40 °C), depending on the pre-designated conditions. The moisture level of the dried kernels was measured with a grain moisture meter (GMK-303HC) of the G-Won Hitech Corporation.

Popcorn-Making and Popping Evaluation

The popcorn was made with a 50 L commercial Kumkang World System popcorn maker, and Haepyo soy bean oil was used to pop the kernels. The amount of kernels in a single batch of popping was 200 g, and the moisture level was measured prior to popping. The degree of popping was determined by measuring the volume of popped kernels and the quantity of unpopped kernels that were passed through the filter of the popcorn maker. As the fluffiness of the popcorn is more important than whether or not it is popped, it was essential to measure the volume. In order to do this, a 3 L stainless bowl was used after being calibrated in four right-angled positions. The average of the values obtained in the four previously marked positions was measured after the bowl was filled and the popcorn was leveled out sparingly.

Sensory Evaluation of Popcorn

For the sensory evaluation, the popcorn was served in a clean disposal cup, and a bottle of water was provided for mouth washing. The sensory evaluation measured four factors: the savory taste, sweet taste, salty taste, and preference. All items were measured on a 5-point Likert scale.

Sensory Evaluation Panels

A total of 15 male and female college students with prior experience of sensory evaluations who had received pre-customized training for the popcorn sensory evaluation took part in the evaluation. The pre-customized training taught them to write a descriptive evaluation of the smell and taste and to attribute proper ratings on the 5-point Likert scale.

Statistical Treatment

A comparative analysis of each control group was performed using SPSS for Windows 10.1. An ANOVA and MANOVA

were performed, and the meaningfulness was tested with Duncan's multiple range test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Popping Effect Comparison According to Saline Concentration Level and Drying Method

Table 1 presents an analysis of the popcorn for kernels treated differently as it changes in the salinity of the soaking solution and various drying methods. An important factor in the qualitative evaluation of popcorn is the degree of kernel popping, i.e., the proportion of the overall volume, the size of each popcorn, and the amount of unpopped kernels (Mohammad, 2011). Looking into the analysis, at the same salinity level of the soaking concentration, drying with a heat-blast dryer produced a lower level of moisture in the kernels. Because, according to Park (1998) and Mohammad (2011), it is the moisture level that affects the popping rate of kernels, their moisture level was measured to 11~13% for non-treated kernels and 12~15% for pre-treated kernels, respectively. This led us to believe, as the salinity level increased, dehydration became less effective, producing kernels with a higher level of moisture. When the total weight of the popcorn and of the unpopped kernels was compared to determine the degree of popping, the kernels soaked in a 0.1% saline solution popped better. Furthermore, the kernels dried by heat-blast after freeze-drying yielded a higher volume than the ones dried by freeze-drying only.

Popcorn Comparison According to Salinity Level and Soaking Time

Popcorn comparison, presented in Table 2, was made among kernels treated with different combinations of conditional variables, including a 0.1% salinity level, 1% salinity level, 30-minute soaking time, and one-hour soaking time. The drying condition, in Table 2, remained constant, involving 30-minute heat blast-drying after two-hour freeze-drying. At the same salinity level, the kernels soaked in a saline solution for 30 minutes dried better, had 11% less moisture, and consequently presented a better popping rate than the ones soaked for one hour. The kernels soaked in a 1% saline solution did not dry out as fast as expected despite a shortened soaking period of 30 minutes, and their popping rate was also low. When a lower amount of oil was used, the popping rate decreased and the number of unpopped kernels increased. The finding was in accordance with the study

Table 1: Popping Effect According to the Soak and Dry Conditions of Kernels

Soak Condition		Dry Condition		Moisture Level of Dried Kernels (%)	Popcorn Weight (g)	Unpopped Kernels (g)
Saline Solution (%)	Soak Time (hr)	Freeze-Drying Time (hr)	Heat-Blast Drying Time (hr)			
0.1	1	2	-	13.4 ± 1.3	139.5 ± 19.1 ^c	45.0 ± 22.6 ^b
		2	0.5	12.2 ± 1.8	166.0 ± 5.0 ^a	21.7 ± 6.4 ^a
0.5	1	2	-	15.1 ± 1.5	149.5 ± 0.7 ^{bc}	37.5 ± 2.1 ^a ^b
		2	0.5	12.6 ± 1.1	163.7 ± 2.3 ^{ab}	22.0 ± 2.6 ^a ^b
1	1	2	-	15.4 ± 1.0	147.5 ± 6.3 ^c	39.0 ± 8.5 ^a ^b
		2	0.5	13.1 ± 1.2	165.0 ± 2.6 ^{ab}	20.7 ± 2.1 ^a

Note: a, b, c Values with different superscripts within the same column show a significant difference at P < 0.05.

Table 2: Popping Effect According to the Salt Concentrations and Soak Time of Kernels

Soak Condition		Dry Condition		Moisture Level of Dried Kernels (%)	Pop-Ping Oil (mL)	Popcorn Weight (g)	Unpopped Kernels (g)	Popcorn Volume (cm)
Saline Solution (%)	Soak Time (hr)	Freeze-Drying Time (hr)	Heat-Blast Drying Time (hr)					
0.1	0.5	2	0.5	11.4 ± 1.0	15	170.0 ± 2.8 ^a	15.0 ± 0.0 ^a	12.7 ± 0.1 ^a
				11.3 ± 0.5	12	166.5 ± 0.7 ^{ab}	17.5 ± 0.7 ^{ab}	12.1 ± 0.4 ^{bc}
				11.6 ± 0.1	10	163.0 ± 1.4 ^b	19.5 ± 0.7 ^{bc}	11.7 ± 0.4 ^{cd}
0.1	0.5	0.5	0.5	12.6 ± 0.4	15	169.0 ± 0.0 ^a	16.0 ± 0.0 ^a	12.3 ± 0.2 ^{ab}
				12.0 ± 0.8	12	168.0 ± 1.4 ^a	15.0 ± 0.0 ^a	11.9 ± 0.2 ^{bc}
				11.7 ± 0.6	10	158.0 ± 2.8 ^c	22.5 ± 2.1 ^c	11.3 ± 0.0 ^d
1	0.5	2	0.5	12.2 ± 0.7	15	167.5 ± 2.1 ^a	16.5 ± 0.7 ^{ab}	12.1 ± 0.2 ^d
				11.8 ± 0.0	12	169.0 ± 0.0 ^a	16.0 ± 1.4 ^a	11.3 ± 0.2 ^{bc}
				12.2 ± 1.0	10	138.5 ± 2.1 ^d	44.0 ± 2.8 ^d	8.5 ± 0.0 ^c

Note: a, b, c Values with different superscripts within the same column show a significant difference at P < 0.05.

maintaining the shape of popcorn and popping rate are affected by the amount of oil added.

Popcorn Comparison According to Freeze-Drying Time

When comparing 30-minute with two-hour freeze-drying, the shorter freeze-drying time of 30 minutes showed both better drying and popping rates with 10% less moisture level based on the comparison of the weight of popped and unpopped corn kernels, and popcorn volume (see Table 3). When comparing the popping rate of non-treated kernels with that of pre-treated kernels, the kernels soaked in a

0.1% saline solution for 30 minutes then dried by heat blast after freeze-drying presented a better popping rate. The amount of oil used also affected the popping rate: the addition of 15mL of oil showed a significantly higher popping rate, particularly in terms of popcorn volume, than that of 13 mL or 10mL of oil. The kernels treated with heat-blast drying after two-hour freeze-drying yielded a similar popping rate to the one expected from non-treated kernels despite consuming 10mL less oil. However, the use of 15mL of oil produced a significantly higher volume from pre-treated kernels than from non-treated kernels popped with 15 mL of oil. For the kernels that were soaked in a 0.1% saline solution

Table 3: Popping Effect According to the Freeze Drying Time of Kernels

Soak Condition		Dry Condition		Moisture Level of Dried Kernels (%)	Pop-Ping Oil (mL)	Popcorn Weight (g)	Unpopped Kernels (g)	Popcorn Volume (cm)
Saline Solution (%)	Soak Time (hr)	Freeze-Drying Time (hr)	Heat-Blast Drying Time (hr)					
0.1	0.5	2	0.5	11.5 ± 0.5	15	173.3 ± 3.9 ^{ab}	13.0 ± 1.8 ^{ab}	12.6 ± 0.4 ^a
				11.3 ± 0.6	13	171.0 ± 5.9 ^{bc}	15.8 ± 4.9 ^{bc}	12.1 ± 0.1 ^{bc}
				11.1 ± 0.2	10	166.7 ± 2.1 ^c	15.7 ± 1.5 ^{bc}	12.0 ± 0.2 ^{bc}
0.1	0.5	0.5	0.5	11.2 ± 0.3	15	178.3 ± 0.8 ^a	10.8 ± 0.8 ^a	12.5 ± 0.2 ^a
				10.9 ± 0.2	13	174.6 ± 2.1 ^{ab}	11.0 ± 1.6 ^a	12.4 ± 0.2 ^{ab}
				10.9 ± 1.1	10	170.8 ± 1.3 ^{bc}	12.5 ± 1.7 ^{ab}	11.9 ± 0.3 ^c
Untreated kernels				11.5 ± 0.1	15	172.4 ± 3.7 ^{bc}	14.4 ± 4.4 ^c	11.9 ± 0.1 ^c

Note: ^{a, b, c} Values with different superscripts within the same column show a significant difference at P < 0.05.

Table 4: Sensory Evaluation of Popcorn¹

Conditions for Treated Kernels				Sensory Evaluation				
Saline Solution (%)	Soak Time (hr)	Freeze-Drying Time (hr)	Heat-Blast Drying Time (hr)	Savory Taste ^{3,4}	Salty Taste	Sweet Taste	Crispy Texture	Overall Preference
1	0.5	0.5	0.5	4.8	2.8	3.8	5.7 ^{ab}	4.5
1	0.5	2	0.5	4.3	2.9	3.7	5 ^{ab}	3.7
0.1	0.5	0.5	0.5	4.7	2.7	3.3	4.9 ^{ab}	3.8
0.1	0.5	2	0.5	4.7	2.3	3	4.9 ^{ab}	3.8
Untreated kernels ²				4.1	2.6	2.4	4.1 ^b	4.1

Note: ¹ All samples were popped with 15 mL soy bean oil. ² It was the control sample. When popped, 4 g of salt was added. ³ Sensory properties were evaluated by a questionnaire using a 5-point scale, where 5 points means 'strongly agree', and 1 point means 'strongly disagree', respectively. ⁴ Values are expressed as mean (n = 15). ⁵ Values with different superscripts within the same column show a significant difference at P < 0.05.

for 30 minutes then dried for 30 minutes using freeze-drying and finally dried by heat blast-drying, the amount of oil added was key to the significantly higher popping rate of the pre-treated kernels. While 13 mL and 15 mL of oil were added to the pre-treated kernels, the popping rate was significantly higher than when 15mL of oil were added to non-treated kernels. Based on these results, it was found that the pre-treatment of kernels could reduce the amount of oil used in popcorn-making by 13 to 30%. It was suggested that the low moisture level produced by freeze-drying and heat blast-drying for different durations led to a better popping rate.

Sensory Evaluation

A total of five types of popcorn prepared under five different

treatment conditions, including 1% salinity for two hours, 1% salinity for 30 minutes, 0.1% salinity for two hours, 0.1% salinity for 30 minutes, and non-treatment, were presented in the sensory evaluation (see Table 4). Upon completion of the evaluation, there was no significant difference in the savory taste, sweet taste, or salty taste. The level of crispness was markedly higher in the four types of popcorn prepared from pre-treated kernels than in that prepared from non-treated ones, and the level of crispness was believed to be affected by the salinity rather than the freeze-drying time. There was no statistically significant difference in the preference. However, the popcorn made from kernels soaked in a 1% saline solution for 30 minutes then dried by freeze-drying for 30 minutes and finally dried by heat blast-drying for 30 minutes was evaluated as having the highest level of

crispness and preference. The analysis of the pre-treatment conditions, popping rate, and sensory evaluation revealed that the popping rate of the kernels could be improved by saline solution-soaking, freeze-drying, and heat blast-drying, and that the amount of oil and salt used to fry popcorn could therefore be reduced. The results also indicated that the optimal conditions for the popping rate, sensory quality, and costs involved soaking in a 0.1% saline solution for 30 minutes then drying by freeze-drying for 30 minutes, and finally drying by heat blast-drying for 30 minutes.

CONCLUSION

This study was designed to identify the optimal pre-treatment conditions for the making of popcorn with a higher popping rate using less oil and salt. Different pre-treatment conditions were applied to the kernels by changing the salinity, soaking duration, drying method, and amount of oil added. The condition yielding the highest popping rate was determined by evaluating the volume of the popcorn and the amount of unpoppered kernels. Moreover, it was determined whether the pre-treatment of kernels affected the sensory quality through a sensory evaluation of the popcorn. The findings suggested that the combination of low-salinity soaking with a shorter soaking time yielded a better popping rate. Regarding the drying conditions, freeze-drying alone yielded a higher moisture level and a lower popping rate than the combination of freeze-drying with heat blast-drying. When two-hour and 30-minute freeze-drying were compared, the shorter freeze-drying time of 30 minutes contributed to the kernels' dryness rate more, and produced a higher popping rate. The amount of oil used was positively correlated with the popping rate, but negatively correlated with the amount of unpoppered kernels. However, the kernels that had been pre-treated produced comparable popping rates despite requiring 13 to 30% less oil than the amount normally needed for kernels with no pre-treatment. The level of crispness was markedly higher in the popcorn prepared from pre-treated kernels than in that prepared from non-treated ones. However, there was no difference in terms of savory taste, sweet taste, salty taste, or preference. The findings of this study suggest that the optimal pre-treatment conditions for kernels involves soaking in a 0.1% saline solution for 30 minutes then freeze-drying for 30 minutes, followed by heat blast-drying for 30 minutes. These conditions are keys to the production of a higher volume of popcorn, and a 30% reduction in oil can also yield a comparable popping volume to that of non-

treated kernels as long as the suggested pre-treatment is correctly applied to the kernels.

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ETHICAL ISSUES/APPROVAL AND DISCLAIMER

I have communicated with all of my co-authors and, and my co-authors and I declare no conflicts of interest. My co-authors have all contributed to this manuscript and approve of this submission to the International Journal of Food and Nutritional Sciences. Neither this manuscript nor substantial parts of it are under consideration for publication elsewhere, been published nor made available elsewhere in a manner that could be construed as a prior or duplicate publication of the same content.

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