Emirates Journal of Food and Agriculture. 2020. 32(7): 543-549
doi: 10.9755/ejfa.2020.v32.i7.2123
http://www.ejfa.me/

RESEARCH ARTICLE

Sensory profiles and hedonic perception of commercial potato chips under blind and informed consumer tests

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ABSTRACT

Although consumer hedonic perception on various food products was evaluated under blind and informed conditions, little research was conducted on commercial potato chips to examine how consumers' perception would change after products' information was disclosed to consumers. Sensory profiles and hedonic perception of six marketed potato chips were investigated under blind and informed conditions, including the specific product manufacturer, nutritional ingredients, and additives. A total of 18 sensory attributes of the chips were profiled by descriptive analysis, and all samples were evaluated under blind or informed conditions by 80 consumers, who rated their acceptance. Significant variations in sensory profiles between tested samples were observed, indicating a broad range of product quality in the marketplace. For the informed consumer test, the health-related positive effect such as oil-free on overall liking scores was not manifested. It suggests that consumers are not willing to compromise on taste, regardless of any benefit, including health. Cluster analysis also showed that no clear market segmentation was observed in both blind and informed evaluations. Therefore, it is concluded that whether potato chips are health-oriented or not is not a key factor in dictating consumers' hedonic perception. Taste is the most important factor affecting consumer choice when purchasing potato chips.

Keywords: Potato chips; Health-oriented; Sensory analysis; Blind and informed test

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a staple food crop in the world. A majority of potato grown worldwide is processed for consumption as potato products, such as potato chips, starch, and french fries, and as food ingredients in snacks or side dishes (Kwak et al., 2015). Potato chips were introduced as snacks over 150 years ago, and are one of the most popular potato snack categories (Kwak et al., 2015), representing approximately 20% of the total USA snack market, and generating sales of over $100 million per year in Korea (Cho et al., 2010).

Potato chips can be broadly classified into 'natural potato chips,' which are produced from fresh potatoes that are washed, peeled, cut, and fried in oil, and 'fabricated potato chips,' made from potato powder and kneaded into a sheet (Korea Food Industry Association and Chung-ang university industry-academic cooperation foundation, 2011). Each of these categories has a further three sub-categories: chips fried in oil, chips sprayed with oil on the surface, and oil-free chips. Among these three sub-categories, chips fried in oil has dominated the potato snack market for a long time because of its distinct, desirable texture and fatty flavor combination (Shedeed et al., 2020). Fat confers desirable texture, flavor, and aroma characteristics on various foods (Rao, 2003). It affects the order that flavor components are released in the mouth, provides lubricating effects, a desirable mouthfeel, and has an important role in satiation. In an emulsion, fat droplets trigger sensations of smooth/creamy/rich texture and flavor (Rios et al., 2014). The melting properties of fat crystals largely determine the spreadability, stability, and other texture attributes to food. As a medium for heat transfer at high temperatures, it generates food textures that are brittle, crunchy, and crispy (McClements and Decker, 2010).

However, increased demand in consumers' preference for health-oriented foods had expanded the choice of low-fat and low-calorie products. To compete in this environment, the potato snack food segment is gradually expanding its manufacture of oil-free potato chips as a healthy alternative to traditional potato chips. Low-fat or

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Received: 02 May 2020; **Accepted:** 14 July 2020

fat-free potato chips should have similar sensory quality compared with traditional fried chips (Oladejo et al., 2018; Wu et al., 2013). To develop a product that meets consumer expectations, factors that affect the quality attributes and consumer preferences of potato chip products need to be objectively studied and validated through scientific methods (Jee et al., 2008).

The success of innovative products in the market mainly depends on consumer acceptability (Temesi et al., 2019). One of the most critical factors for consumer acceptability is flavor or expected flavor of the product (Jonas et al., 1998; Krutulyte et al., 2008; Poulsen, 1999). Some authors reported that consumers did not seem willing to compromise on flavor, regardless of the food product's health benefits or any other positive effects (Kraus, 2015; Lalor et al., 2011; Lyly et al., 2007). However, it is widely recognized that consumer acceptance can be affected by not only intrinsic factors, such as the sensory characteristics of the product, but also by extrinsic factors, including product brand, ingredients, or packaging etc (de Andrade et al., 2018; Jaeger, 2006).

Although commercial oil-free potato chips are becoming more interesting to consumers, studies that identify the relationship between the extrinsic factors of products described above and their consumer acceptability are rare. Therefore, it is warranted to study consumer perception for commercial potato chips including oil-free potato chips under informed conditions (Asioli et al., 2017). Research investigating the sensory and hedonic perception of commercial potato chips in Korea by blind or informed consumer tests has not yet been addressed in the literature, therefore representing both a research and market opportunity. This study was conducted to evaluate the sensory profile and hedonic perception of six marketed potato chips, including oil-free products, under blind and informed conditions.

MATERIALS AND METHODS

Sample collection

Six commercial potato chips were obtained from a local market in Korea. Chips with a broad range of sensory properties and most consumed in Korea were selected for this study. Four chips were conventional, which were fried in oil ranging from 16 % to 22 % of fat content, while the other two chips were oil free. A total of 20 bags were purchased for each brand. All the potato chip bags had a similar date of manufacture, indicating a similar shelf life. Chips were kept at 20±1 ºC prior to all the analyses. The detailed information on the products used is shown in Table 1.

Descriptive analysis

An experienced (more than 1 year) panel of eight subjects (6 female and 2 male, age range 21–31 years) conducted the descriptive analysis of the various food products, including snacks. They had extensive experience in establishing and evaluating flavor and texture lexicon of food.

A total of 18 attributes related to the appearance, flavor, and texture of potato chips were established on consensus and evaluated on 15-point numerical scales (Table 2). Two 5-h orientation sessions were held for the panelists to familiarize themselves with the testing procedure and minimize the variation among the panelists. Panelists performed all tests in individual booths with adequate lighting to minimize any potential psychological biases associated with the samples. Samples (duplicates) were presented in a completely randomized block design (block = replication). Each session was followed by a 15-min break. Panelists were asked to cleanse their palates with water between evaluations. Side-by-side methodological comparisons of samples were made for the evaluation of each attribute to allow intensity comparisons within the samples.

Table 1: Descriptions of potato chips used in this study

Name of potato chip (Abbreviation)	Name of manufacturer	Potato content(%)	Fat content(%[1)])	Ingredients
Potatochip (PTC)	Nongshim	91	22	Potato, Rice bran oil, palm oil, Seasoned salt
Pockachip (PKC)	Orion	90	20	Potato, Mixed edible oil(Palm olein oil, sunflower oil), Seasoned salt, synthetic flavor
Sumi potato chip (SMC)	Nongshim	94	16	Potato, Rice bran oil, palm oil, Seasoning salt powder, Roasted sun salt
Muddukdduk potato chip (MDD)	Orion	85	20	Potato, Vegetable oil 1(Palm olein oil, sunflower oil), pepper salt seasoning, Vegetable oil 2
Just like your name potato chip (JLN)	Lotus flower village	100	0	Potato
Uniontech potato chip (UNT)	Uniontech	100	0	Potato,

[1)]The % Daily Value indicates how much a nutrient in 30g of products to a daily diet, 2,000 calories a day is used for general nutrition advice

Table 2: Mean intensities of sensory attributes for potato chips

	Attributes	Samples					
		MDD	PKC	PTC	SMC	JLN	UNT
Appearance	Yellowness	8.2[a1)]	4.9[bc]	6.4[ab]	3.3[cd]	6.6[ab]	2.1[d]
	Thickness	10.4[a]	4.3[cd]	4.4[cd]	6.0[bc]	6.9[b]	3.8[d]
	Foamability	6.9[b]	5.1[b]	4.8[b]	5.2[b]	10.4[a]	9.6[a]
Odor/Aroma	Potato	5.3[bc]	7.6[ab]	9.0[a]	7.1[ab]	3.8[c]	4.4[c]
	Oil	6.8[a]	7.6[a]	8.3[a]	6.8[a]	3.1[b]	3.3[b]
Taste	Sweetness	3.3[abc]	4.5[a]	2.9[abc]	3.5[ab]	2.0[bc]	1.4[c]
	Saltiness	11.0[a]	9.5[ab]	7.3[c]	7.9[bc]	2.8[d]	2.3[d]
	Umami	7.9[a]	6.8[ab]	5.3[bc]	5.1[bc]	3.2[c]	3.0[c]
	Pepper	10.8[a]	5.9[b]	4.8[bc]	3.8[cd]	1.8[de]	1.4[e]
	Potato	7.9[ab]	9.2[a]	8.5[ab]	7.4[ab]	5.9[b]	6.8[ab]
	Starch	3.7[c]	4.8[c]	5.3[c]	5.0[c]	8.4[b]	10.3[a]
	Acridity	3.9[bc]	4.7[abc]	3.4[c]	3.7[bc]	6.3[ab]	6.5[a]
Texture/ Mouthfeel	Brittleness	7.6[a]	6.1[a]	5.1[a]	5.4[a]	6.6[a]	7.1[a]
	Hardness	10.1[a]	4.4[c]	3.8[c]	5.5[bc]	7.1[b]	5.5[bc]
	Crispness	11.0[a]	8.6[ab]	8.1[b]	8.9[ab]	9.9[ab]	8.5[b]
	Cohesiveness	4.8[a]	5.8[a]	6.6[a]	5.6[a]	4.4[a]	5.2[a]
	Adhesiveness	6.8[a]	5.6[a]	7.4[a]	7.1[a]	5.9[a]	7.1[a]
	Greasy	7.9[ab]	8.8[a]	7.4[ab]	6.1[b]	2.4[c]	2.7[c]

Product names are the same as in a Table 1. [1)]Different superscripts in the same row are significantly different at $p<0.05$

Consumer acceptance test

This study was approved by the Institutional Review Board of Dankook University in Korea (approval number: DKU 2018-07-014). A total of 80 consumers who had consumed potato chips at least twice a week participated in the test. Age of consumers participated was ranged from 20's to 50s, while the ratio of male and female was almost the same. The test was performed under blind and informed conditions because how consumers' perception would change after the products' information was disclosed to consumers was of key concern in this test. All tests were administered as a home-use-test. The blind test, in which samples were presented with 3-digit random codes without any type of product information, was followed by the informed test. For the informed test, six identical samples with the same blind test coded 3-digit numbers were given to consumers. Approximately 20 g of each sample (10–20 pieces of chips depending on the sizes) was repackaged in aluminum foil bags (10.0 × 15.0 cm) and given to each consumer, along with the product information, including its photo, name, raw material contents, and nutritional information. A preliminary test was conducted to monitor the moisture content of the repackaged samples during 7 days of storage. The moisture content of the repackaged samples was stable over 7 days of storage (data not shown). A 9-point hedonic scale was used.

Statistical analysis

XLSTAT version 2019 (Addinsoft, Paris, France) software was used for the statistical analyses. Sensory and consumer data were analyzed by two way analysis of variance (ANOVA), followed by Tukey's multiple range test at $P < 0.05$ when significance existed. Products were treated as fixed effects, while panelist and panelist by product interaction (if significant, $\alpha = 0.05$) were treated as random effects. The interaction was used as the error mean square in denominator of the F-statistics for testing product variations. Principal component analysis (PCA) was performed using descriptive analysis results to identify the relationship between the products and their sensory attributes. An independent *t*-test was run to identify significant differences between blind and informed groups in their ratings of overall liking (OL), appearance, flavor, and texture of each sample. Agglomerative hierarchical clustering analysis based on Ward's method was used to cluster each blind and informed group of consumers based on their OL of the samples. The OL of each cluster in the blind and informed groups was analyzed by ANOVA, and the means were separated by Tukey's multiple range test at $P < 0.05$. PCA was then conducted for each test-type group (blind and informed) to identify consumer's acceptability of the samples.

RESULTS AND DISCUSSION

Descriptive analysis

The mean values of the descriptive sensory attributes for each product are shown in Table 2. The interactions between the products and panelists for all the sensory attributes were not significant ($P < 0.05$), indicating that the chips tested were perceived similarly by the panelists.

All 12 flavor-based attributes, including appearance, but just half out of the six texture-related attributes showed significant differences. This result implies that the presence and absence of oil in commercial chips have a greater effect on flavor than the texture of the product (Garayo and Moreira, 2002). In addition, different seasonings in products might also impart different effects on the flavors of the products. Interestingly, significant differences were observed for hardness, crispness, and greasiness among products. Hardness and crispness were the highest for MDD. However, MDD had the highest thickness (Table 2), and this could have affected these results because no clear trends of hardness and crispness were found for both oil and oil-free products. It has been reported that the thickness of potato chips could be positively correlated with their sensory texture properties (Salvador et al., 2009). As expected, products JLN and UNT were the least greasy because of their oil-free characteristics.

Among the appearance attributes, the yellowness and thickness of MDD were significantly higher than the other products. The color of potato chips has been associated with the content of reducing sugars in potato (Kumar et al., 2004). Although the reducing sugars were not measured in this study, we suppose that MDD might have a higher content of reducing sugars than the other products. As the storage period of potato increases, the amount of reducing sugars increases as well (Kumar et al., 2004). Surface foamability was highest for JLN and UNT. This observation might be attributed to a different manufacturing process for JLN and UNT compared with the other products, although the exact manufacturing process of the products was unknown. It is noteworthy that JLN and UNT are not fried in oil, but instead baked in a conventional or microwave oven, which might lead to insufficient gelatinization of the potato starch (Ravli, 2012). Another possible explanation for their high surface foamability would be that there is a larger amount of potato in these products than the other products. It was reported that the higher the starch content of potato chips, the less likely they might be gelatinized (Kawai et al., 2007).

Three basic tastes, namely sweet, salty, and umami, were highest in MDD, PKC, PTC, and SMC. These products contained additives, such as processed seasoning salts (Table 2). Pepper flavor was the strongest in MDD because only MDD contained pepper. It is considered that the saltiness and umami of MDD were significantly higher as a result of the higher amount of additives, including salt seasonings or pepper, relative to the other samples. Pepper is often used as a saltiness substitute (Shin and Lee, 2010), so samples that were saltier than others were considered to have strong pepper flavor. Acridity and starchy flavor were significantly higher for UNT and JLN than the other samples. It is thought that the starchy flavor of potato was strong because only UNT and JLN did not contain any additives. Insufficient starch gelatinization of these products, as discussed above, could be another possible reason. Acridity is known as a combination of spicy, astringent, and bitterness, which is a colloidal taste when starch contacts the tongue receptors (Lee, 1992).

To visualize the relationships of products with their attributes, PCA was performed using six products and 15 attributes that showed statistical significance ($P < 0.05$). The PCA biplot explained 84.77% (F1:55.01%, F2: 29.76%) of the total variation (Fig. 1). The F1 dimension mainly accounted for attributes of oil aroma, sweetness, saltiness, umami, potato flavor, pepper flavor, and greasy. The samples of MDD, SMC, PTC, and PKC had high (positive) sensory values for these characteristics. In the opposite (negative) direction were the attributes of foamability, starchy flavor, and acridity, and the samples of JLN and UNT. Attributes of thickness, crispness, and hardness, and samples of MDD and JLN were loaded positively on F2. For each sample, MDD showed higher yellowness, pepper flavor, umami, and saltiness, whereas JLN had higher foamability and acridity. UNT had a more intense starchy flavor than the other samples. SMC, PKC, and PTC showed similar sensory attributes to each other, and prominent characteristics of potato flavor, oil flavor, sweetness, and greasy.

Consumer acceptability between blind and informed groups

Results of the consumer acceptance test for the blind group evaluated without product information, and the informed group that provided product information are presented in Table 3. Consumer liking attributes were significantly influenced by the products, as well as the

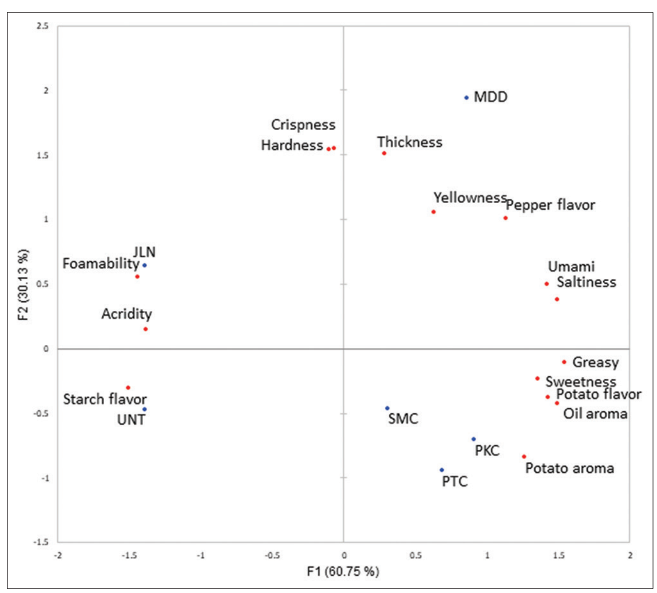

Fig. 1. PCA loadings for sensory attributes and the scores of the potato chips. Product codes are as Table 1.

Table 3: Overall liking, appearance, flavor and texture for potato chips according to test types (blind or informed test)

Sample	Overall liking		Appearance		Flavor		Texture	
	Blind	Informed	Blind	Informed	Blind	Informed	Blind	Informed
UNT	$4.6^{c\,1)}_{ns}{}^{2)}$	4.3^{c}	5.1^{c}_{A}	4.5^{c}_{B}	4.1^{d}_{ns}	3.7^{d}	5.3^{c}_{A}	4.5^{c}_{B}
SMC	$6.1^{b}_{B}{}^{3)}$	6.6^{a}_{A}	6.0^{ab}_{B}	6.5^{a}_{A}	6.1^{b}_{B}	6.6^{ab}_{A}	6.0^{b}_{B}	6.6^{a}_{A}
PTC	5.9^{b}_{ns}	6.0^{ab}	6.2^{ab}_{ns}	6.3^{ab}	5.9^{bc}_{ns}	6.0^{bc}	5.9^{bc}_{ns}	6.0^{ab}
PKC	6.9^{a}_{ns}	6.5^{a}	6.5^{a}_{ns}	6.4^{a}	7.0^{a}_{ns}	6.8^{a}	7.0^{a}_{ns}	6.7^{a}
MDD	5.4^{b}_{ns}	5.6^{b}	5.8^{bc}_{ns}	5.7^{b}	5.4^{c}_{ns}	5.5^{c}	5.2^{c}_{ns}	5.4^{b}
JLN	3.4^{d}_{B}	4.1^{c}_{A}	3.9^{d}_{ns}	4.3^{c}	3.0^{e}_{B}	3.6^{d}_{A}	3.7^{d}_{ns}	4.2^{c}

Product names are the same as in a Table 1. [1)]Different superscripts in the same column for each test type are significantly different at $p<0.05$. [2)]"ns" means "not significant" at $p<0.05$.[3)]Different subscript in the same row for each test type are significantly different at $p<0.05$

evaluation methods. PKC received the highest score in OL, while JLN was least liked by consumers under the blind condition. For the informed evaluation, SMC, PKC, and PTC obtained the highest liking scores, while UNT and JLN were grouped in the lowest liking category. The reason SMC and PKC were shifted up to the highest liking group after product information was disclosed to consumers under the informed test could be related to brand power or familiarity of products (Paasovaara et al., 2012). Products SMC and PKC were known to be two of the top-selling conventional products in Korea. The same explanation could be reasoned for the lowest liking groups considering that UNT and JLN have relatively low brand power in Korea's snack market. It would be also interesting to note that although products UNT and JLN were oil-free products, it failed to draw consumer's attention in liking. This is interesting because the effect of health-related factors was not great contrary to expectations in selecting potato chips. This would be more discussed hereafter.

Jaeger (2006) reported branding of products plays a key role in consumers' acceptability of food products. Well-known branded products can add additional value to products, including consumer familiarity, unique features, purchase royalty, or positive recognition (Anselmsson et al., 2007; Krystallis and Chryssohoidis, 2005). The reason is that the product brand can serve as a relevant quality cue for consumers, as consumers would buy these products on a regular and routine basis under time pressure (Bredahl, 2004). Research (Ares et al., 2010; Arnade et al., 2008; Cohen and Goodman, 2009) has demonstrated that familiar brands could be associated with consumers' attributes or intentions toward products, such as purchase intentions, choice preferences, and repurchase intention.

Yan et al. (2015) stated that health-related information on products might increase consumer preference when buying snacks. However, it was observed that the impact of product information of oil-free products (UNT and JLN) on OL values were minimal in this study (Table 3). Despite knowing there is no fat in chips, an informed test can potentially increase the acceptability of the product, but it did not happen in this study. Such a result could imply that consumers consider taste over any other information about the products when buying potato chips. Consumer acceptance toward food products is more likely influenced by taste or expected taste of the product than any positive health aspect associated with its consumption (Krutulyte et al., 2008). Several studies demonstrated that consumers were not willing to compromise on products' taste or purchase food products in exchange for products' positive health effects (Kraus, 2015; Lalor et al., 2011; Lyly et al., 2007).

The mean OL scores of the products depending on the consumer clusters according to test type are shown in Table 4. In the blind group, cluster 1 consisted of 40% of the panel (n = 32). Consumer acceptability of oil-free products was higher in cluster 1 than cluster 2, which had relatively higher consumer acceptability of fried products. As a result, cluster 1 could be considered as a group that preferred oil-free products. However, differences in OL according to each cluster were minimal. No clear market segmentation was observed in both blind and informed evaluations, although slight increases in OL values were found for some of the products (SMC, PTC, PKC, and MDD) for cluster 2 under the informed test. This outcome provides further support that the effects of product information on the OL of chips are minimal. Instead, consumer liking perception is driven by the sensory profiles or any other extrinsic information of products. This finding corroborated with previous studies that found no significant effects on consumer hedonic response when product label information was disclosed (Meier-Dinkel et al., 2013). Therefore, it can be concluded that the information as to whether chips contain oil or are oil-free is not a drastic factor in determining consumer hedonic perception. The PCA was conducted to visualize the orientation of consumers' preference for each cluster in the blind (Fig. 2A) and informed (Fig. 2B) groups.

Most of the consumers in the blind and informed groups were on the positive F1-axis. Compared with the blind group, the points of some consumers in the informed group moved to negative F1-axis in the UNT and JLN

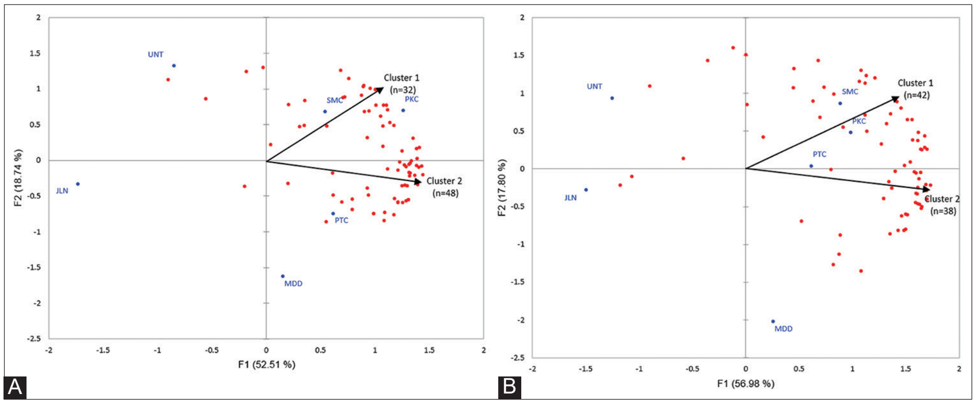

Fig. 2. PCA on consumer overall liking of potato chips under blind test (A) and informed test (B). Squares and circles are samples and consumers. Arrows are the directions for center points of each cluster from the agglomerative hierarchical clustering analysis.

Table 4: Mean overall liking for potato chips depending on consumer clusters by agglomerative hierarchical clustering analysis according to test types (blind or informed test)

	UNT	SMC	PTC	PKC	MDD	JLN
Blind						
Cluster 1 (n=32)	$5.1^{bc1)\ 2)}_{A}$	$5.7^{ab\ 3)}_{ns}$	4.5^{cd}_{B}	6.2^{a}_{B}	4.2^{cd}_{B}	3.6^{d}_{ns}
Cluster 2 (n=48)	4.2^{c}_{B}	6.3^{b}	6.8^{ab}_{A}	7.4^{a}_{A}	6.2^{b}_{A}	3.3^{d}
Informed						
Cluster 1 (n=42)	4.6^{cd}_{A}	6.2^{a}_{B}	5.2^{bc}_{B}	5.7^{ab}_{B}	4.5^{cd}_{B}	4.2^{d}_{ns}
Cluster 2 (n=38)	3.9^{b}_{B}	7.1^{a}_{A}	7.1^{a}_{A}	7.4^{a}_{A}	6.7^{a}_{A}	3.9^{b}

Product names are the same as in a Table 1.[1)]Different superscripts in the same row for each test type are significantly different at $p<0.05$.[2)]Different subscript in the same column for each test type are significantly different at $p<0.05$.[3)]"ns" means "not significant" at $p<0.05$

direction. In addition, consumers on the PCA biplot moved from cluster 2 that disliked oil-free potato chips to cluster 1 that preferred oil-free potato chips. The reason is the similarity of the attributes in the descriptive analysis, and the raw material content of the samples.

CONCLUSIONS

The overall sensory quality of commercial potato chips currently marketed in Korea was found to vary significantly. The significant variations in the quality of chips seemed to be attributed mainly to, firstly, whether the chips were fried in oil or fat-free, and second, the different seasonings used in the manufacturing process. Under informed test with disclosing the product information to consumers, the effect of brand power or familiarity of products was observed, allowing some products' liking to increase. Interestingly, the positive effect from product information of oil-free products (UNT and JLN) on OL values was not noticeable, suggesting that consumers put more emphasis on taste than product information when buying potato chips. Consumers seemed unwilling to compromise on products' taste. Accordingly, it is summarized that whether potato chips are fried or not is not a major factor in determining consumer hedonic perception. Taste is the most important factor affecting consumer choice when purchasing potato chips. The results are limited to potato chips with 80 consumers, and the extension of this study to different types of snacks with larger number of consumers could be an interesting research avenue to pursue.

ACKNOWLEDGEMENTS

This research was supported by the research fund of Dankook Univ. in 2020.

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