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Effect of Hot-air Dried *Lentinula edodes* pileus on the Quality and Organoleptic Properties of Rolled-dumplings

ABSTRACT

The effect of hot-air dried *Lentinula edodes* pileus (DLE) on the quality and organoleptic properties of rolled-dumplings was evaluated. DLE was prepared by drying at 60℃ for 24 h and added (Non, 7, and 9%) to rolled-dumplings. The proximate composition, pH, color (CIE L^*, a^*, b^*), and cooking yield were analyzed. Texture profile analysis (TPA), electronic-nose (e-nose), electronic-tongue (e-tongue), and organoleptic evaluation were also conducted. The cooking yield of dumplings with 9% DLE was significantly lower than that of the congeners without DLE, whereas 7% DLE did not lead to significant differences compared without DLE. With increasing DLE addition, the pH and lightness of the dumplings decreased significantly, whereas the redness tended to increase. The texture profile was significantly higher for the dumplings with DLE compared to those without DLE. E-nose analysis confirmed that DLE addition led to the positive odors (methanethiol: meaty, sulfurous; 3-methylbutanal: malty, toasted) and the negative odors (trimethylamine: ammoniacal; acetic acid: acidic, sour). E-tongue analysis showed that DLE addition decreased the intensity of the sourness and increased the intensity of the saltiness and umami of rolled-dumplings. DLE addition improved the overall organoleptic properties, but 9% DLE can be recognized as a foreign substance in organoleptic acceptance. Consequently, DLE has the potential to serve as a flavor and odor enhancer for rolled-dumplings, and the addition of DLE can positively improve consumer acceptance by improving the quality and organoleptic properties.

Key words: hot-air drying, *Letinula edodes*, rolled-dumplings, quality properties, organoleptic properties

1. Introduction

A home meal replacement (HMR) is a complete or semi-cooked product sold for immediate or simple cooking. The market for HMRs has continued to grow due to an increase in the proportion of single-person households and improvements in the variety, convenience, and taste of HMR products (Kim et al., 2017; Lee, 2017). HMRs are generally classified as ready to eat (RTE), ready to heat (RTH), ready to cook (RTC), and ready to prepare (RTP) according to the cooking method (Bae et al., 2020). The proportion of livestock food, the main ingredient in HMR, was 61% in 2020 in Korea, which increased by 7% compared to the previous year. Therefore, the release of various products, including processed meat products such as soup, stew, Jjigae, hot pot, cup rice, and frozen side dishes, is in demand (aTFIS, 2020).

Dumplings are products made by filling and molding dumpling skins made of wheat flour or buckwheat flour dough with dumpling stuffing containing meat, fat, vegetables, and other additives (Zhang et al., 2011). The types of dumplings in various recipes are tailored to a specific lifestyle by changing the ingredients. There are various dumplings such as pheasant dumplings filled with pheasant meat, mullet dumplings containing sliced mullet, and rolled-dumplings made by rolling the dumpling stuffing in flour without the dumpling skin (Kim and Ahn, 2019). Recently, dumplings with various ingredients have been released according to consumer preference, such as hotteok (Korean pancake) dumplings with tomato sauce, cream cheese, red bean, and seeds, and X.O. rolled-dumplings with Dongpo pork, shrimp, red crab meat, and mala (Chinese spice) sauce (aTFIS, 2019). These dumplings can be manufactured according to the variety of ingredients and are suitable for producing products that meet the needs of consumers.

Lentinula edodes (LE) is an edible mushroom that belongs to the genus *Lentinula*, family *Omphalotaceae*, order Agaricales, class Agaricomycetes. LE contains nucleic acid-based seasoning ingredients such as guanylic acid and adenylic acid, which confer a unique flavor, and is used in Eastern and Western cuisines where it is consumed in various ways (Kim et al., 2012; Morales et al., 2020; Yun et al., 2020). LE contains lentinan, a water-soluble polysaccharide, eritadenine, ergosterol, phenol, and various physiologically active substances, which lower blood pressure and blood cholesterol levels and exert antiviral and anticancer activity, and improve immunity (Liu et al., 2020; Xu et al., 2019). In addition, it is an excellent source of protein and dietary fiber and has a texture characteristic similar to that of meat, so that when applied to meat products, it does not significantly affect the existing formulation (Cerón-Guevara et al., 2020; Wang et al., 2019. In the process of drying LE, vitamin D is activated, and the umami taste is improved due to the increased content of 5'-guanosine monophosphate, thereby improving the nutritional and organoleptic properties (Kong et al., 2019; Qin et al., 2020). In addition, the concentration of antioxidant compounds such as polyphenols liberated by the destruction of the cell wall during the hot-air drying (HAD) process also increases, and the antioxidant activity increases due to the Maillard reaction (Choi et al., 2006; Manzocco et al., 2000).

The electronic-nose (e-nose) and electronic-tongue (e-tongue) are gas and liquid sensor array systems that mimic the human senses of smell and taste, and are used to analyze volatile compounds and taste-related compounds (Buratti et al., 2018). When analyzing food quality, the organoleptic properties and processing parameters related to quality can be analyzed relatively inexpensively and quickly using the e-nose and e-tongue compared to gas chromatography–mass spectrometry, laser scattering analyzer, or high-performance liquid chromatography (Tan and Xu, 2020). Although the e-nose and e-tongue are limited for quantitative analysis, microscopic differences in the taste and smell of food caused by various factors can be specified and distinguished (Weng et al., 2021). Therefore, the e-nose and e-tongue are used in the field of analysis of various foods such as smoked and fermented meat products because it is possible to objectively analyze flavor and taste instead of direct organoleptic evaluation of food (Chen et al., 2021; Zhang et al., 2021a; Zhang et al., 2021b).

LE exhibits unique organoleptic properties due to the various physiologically active substances, and is thus able to improve the quality of meat products. However, LE has been used in dumplings in only a few cases. Therefore, this study intends to analyze the effect of LE subjected to the HAD process (i.e., DLE) on the quality and organoleptic characteristics of rolled-dumplings.

2. MATERIALS AND METHODS

2.1. Preparation of rolled-dumplings

2.1.1. Preparation of materials

Pork hind legs were purchased from Hongjumeat (Hongseong, Korea) 24 h after slaughter and prepared by grinding with a grinder (PA-32, Mainca, Barcelona, Spain) equipped with a 3 mm plate. The ingredients for the rolled-dumplings were purchased from Hanaro Mart in Yesan, Chungnam, and salt was purchased from Hanju Salt (Ulsan, Korea). LE was divided into the pileus and stem and dried at 60℃ for 24 h in a drying oven (C-F03, Vision Scientific, Daejeon, Korea), after which the pileus was chopped into cubes (1 cm) to prepare DLE (hot-air dried *Lentinula edodes* pileus). Mushroom oil was prepared by frying the dried LE stems with cooking oil at a ratio of 1:20, then filtering the oil with filter paper (Whatman No. 1, GE Healthcare, Chicago, IL, USA). As auxiliary ingredients, chestnuts were steam-cooked at 120℃ for 20 min in a chamber (10.10ESI/SK, Alto Shaam, Menomonee Falls, WI, USA) and then pulverized with a hand blender (HR2652, Philips, Amsterdam, Netherlands). Tofu was mashed and dehydrated, and leek, cabbage, green onion, onion, and garlic were finely chopped.

2.1.2. Preparation of DLE rolled-dumplings

Pork hind legs (50%), tofu (36%), garlic chives (7%), and cabbage (7%) were used as the main ingredients for filling the dumplings. Compared to the total weight, as auxiliary ingredients, 7% chestnut, 5% honey, 3% mushroom oil, 1% salt, 1.4% leek, onion and garlic, 0.2% isolated soy protein (ISP), 1% monosodium glutamate (MSG), and DLE (Non, 7, and 9%) were added. After hand mixing for 2 min, the mixture was covered with plastic wrap and aged in an aging-refrigerator (DA-45, The Alesso, Seoul, Korea) at 4℃ for 30 min. The prepared dumpling stuffing was weighed to about 20 g and formed into a spherical shape. There0after, potato starch was thinly applied to the surface and heated in a chamber (10.10ESI/SK, Alto Shaam) at 120℃ for 7 min. The prepared rolled-dumplings were left to cool at 10˚C for 20 min and then stored at 4℃ and used in the experiments within 24 h.

2.2. Physicochemical and organoleptic analysis of rolled-dumplings

2.2.1. Proximate compositions

The proximate compositions of the rolled-dumplings were measured and calculated by converting the moisture content (AOAC-925.10), protein content (AOAC-960.52), fat content (AOAC-2003.05), and ash content (AOAC-923.03) according to AOAC (2005). The carbohydrate content was calculated by excluding the sum of the moisture, protein, fat, and ash contents from the total content (100%) based on proximate analysis (Alakali et al., 2010).

2.2.2. pH

The dumpling stuffing before cooking was homogenized at 6,451 ×g for 1 min using an Ultra-turrax (HMZ-20DN, Poonglim Tech, Seongnam, Korea) instrument by adding 4 g of sample and 16 mL of distilled water, and the pH of the rolled-dumplings after cooking was measured. The pH of the homogenized sample was measured using a glass electrode pH meter (Model S220, Mettler-Toledo, Schwar-zenbach, Switzerland). The pH meter was calibrated using pH 4.01, pH 7.00, and pH 10.00 buffer solutions (Suntex Instruments Co. Ltd., New Taipei City, Taiwan).

2.2.3. Color

The CIE L^* (lightness), a^* (redness), and b^* (yellowness) color coordinates were measured using a colorimeter (CR-10, Minolta, Tokyo, Japan) with a wide angle of 8°. The surface of the dumpling stuffing was analyzed before heating and an inner cross-sectional cut was made based on the spherical point of the rolled-dumplings 10 min after cooking. The CIE data were acquired using a standard D_{65} light source, and a white standard plate with CIE L^* +97.83, CIE a^* −0.43, and CIE b^* +1.98 was used for the standard color.

2.2.4. Cooking yield

The cooking yield (%) of the rolled-dumplings was calculated after cooking at 120℃ for 7 min in a steam chamber (10.10ESI/SK, Alto Shaam) and cooling for 20 min at 10℃. The weight was measured before and after cooking.

$$\text{Cooking yield (\%)} = \text{Weight after cooking (g)}/\text{Weight before cooking (g)} \times 100$$

2.2.5. Texture profile analysis (TPA)

TPA force evaluation of the rolled-dumplings was performed using a texture analyzer (TA1, Lloyd, Largo, FL, USA) for a spherical sample of Ø 3.5 cm. The spherical sample was tested by fixing it to make it immobile when a machine force was applied. For the TPA, the hardness (kg), springiness, and cohesiveness were measured, and constant values for the gumminess (kg) and chewiness (kg) were calculated using these parameters.

2.2.6. E-nose

The e-nose analysis was performed by using a flash gas chromatography e-nose (Hercules NEO, Alpha MOS, Toulouse, France). The rolled-dumpling sample (5 g) was placed in a 20 ml head-space vial, sealed with a lid, and stirred at 80℃ for 20 min; 5 ml of volatile compounds was collected through an automatic sample collector. After setting the injection rate to 125 μL/s and the injection temperature to 200℃ in the injected gas chromatography injection port, the injected volatile compounds were simultaneously analyzed at a trap absorption temperature of 80℃, trap desorption temperature of 250℃, and acquisition time of 110 s in two columns (MXT-5/MXT-1701, Restek, PA, USA). An alkane C_6–C_{16} standard solution was used to identify the components based on Kovat's index.

2.2.7. E-tongue

The e-tongue analysis was performed using a taste sensor e-tongue (Astree V, Alpha MOS, Toulouse, France). A sample of rolled-dumplings (8 g) was homogenized for 1 min at 6,451 ×g using 32 ml of distilled water and a homogenizer (AM-5, Nissei). The homogenized sample was filtered with filter paper (Whatman No. 1, GE healthcare) and the supernatant was collected. The supernatant was diluted 1,000-fold in distilled water and measured using the taste sensor e-tongue. The analysis measured the signal intensity at each sensor using taste sensors: CTS (saltiness), NMS (umami), and AHS (sourness), along with auxiliary sensors SCS and CPS, and standard sensors PKS and ANS.

2.2.8. Organoleptic evaluation

The organoleptic evaluation was conducted by selecting a panel of eight trained personnel who were familiar with and had sufficient knowledge of the terms and evaluation criteria for the samples in accordance with the Research Deliberation (Authority No: KNU 2020-40) of the Kongju University Institutional Review Board (IRB). For the organoleptic evaluation, the heated dumplings with different amounts of DLE were evaluated on a scale of 1–10 for each of the six major sensory characteristics, and the average value was obtained and compared. In terms of color, flavor, texture, juiciness, and overall acceptability, 10 points indicated the best quality (10 = extremely good or desirable), and 1 point indicated the worst quality (1 = extremely bad or undesirable). In terms of off-flavor, 10 points indicated that the off-flavor was least perceived (10 = not strongly perceived), and 1 point indicated that the off-flavor was strongly perceived (1 = strongly perceived).

2.2.9. Statistical analysis

All experiments were repeated at least three times; the experimental results were evaluated by one way analysis of variance (ANOVA) using the statistical processing program SAS (version 9.4 for Windows, SAS Install Inc., Cary, NC, USA). Thereafter, significant differences ($p<0.05$) between the groups were verified by the Duncan's multiple range test. The e-nose and e-tongue data were analyzed using Alphasoft 14.2 (Alpha MOS, Toulouse, France). The difference between the e-nose data for the samples was determined through principal component analysis (PCA) and from the mean bar graphs (peak area $\times 10^3$, data indicating 95% or more of the discrimination power), and the e-tongue data were interpreted using a radar chart and intensity scale bar chart.

3. Results and discussion

3.1. Proximate composition and cooking yield

Table 1 shows the proximate composition of the rolled-dumplings with various DLE (moisture: 14.62 ± 0.22%, protein: 14.29 ± 1.55%, fat: 0.49 ± 0.11%, ash: 3.68 ± 0.46%, carbohydrate: 66.97 ± 2.15%) contents. The moisture content decreased significantly as the amount of added DLE increased ($p<0.05$ The dietary fiber content of DLE is known to be 23.23% (Gaglarirmak, 2011). Thus, when DLE was added, the behavior was similar to that in a previous study, where the moisture content decreased when dried shiitake mushrooms with a dietary fiber content of 18.31% were added to pork sausage (Stefanello et al., 2015; Tsai et al., 2008). It is also known that LE loses its ability to prevent water loss due to disruption of the integrity of the cell membrane when exposed to temperatures of 60℃ or higher (Qiu et al., 2021). Therefore, it is considered that the decrease in the moisture content of rolled-dumplings may be due to the destruction of the cell membrane by heating, and on the other hand, the moisture content may be affected by the relative increase in the carbohydrate content. On the other hand, the protein, fat, and ash contents of the rolled-dumplings were not significantly affected by DLE addition ($p>0.05$). It is considered that the protein, fat, and ash content of DLE was relatively low compared to the carbohydrate content, so it did not directly affect the rolled-dumplings significantly. However, LE can be considered as a food additive as a good source of protein and minerals (Spim et al., 2021). The carbohydrate content was significantly higher for the samples with DLE addition than for those without DLE ($p<0.05$). Bach et al. (2017) reported that the carbohydrate content of LE was 70.91%. The increase in the carbohydrate content of the rolled-dumplings with increasing DLE addition is considered to be due to the high carbohydrate content of DLE.

Fig.1 shows the cooking yield of the rolled-dumplings according to the addition of various

DLE. There was no significant difference in the cooking yield of the rolled-dumplings without DLE and those with 7% DLE. However, the cooking yield of the samples with 9% DLE was significantly lower ($p<0.05$). The protease activity of LE is 13.01 U/g, which is similar to that of kiwi (10.26 U/g) and pineapple (19.58 U/g), which are used as meat tenderizers (Oosone et al., 2020). Qing et al. (2021) reported that when paddy straw mushroom, shimeji mushroom, and oyster mushroom powders were added to beef paste, water bound to the meat tissue was exuded by proteolysis due to the protease contained in the mushroom, thereby reducing the cooking yield, which is similar to the result of this study. In addition, Wang et al. (2019) reported that when some of the pork used in sausages was replaced with LE, the water retention ability of LE decreased during the cooking process as the LE level increased, resulting in a decrease in the cooking yield. Therefore, it is thought that the decrease in the cooking yield of the rolled-dumplings with 9% DLE is due to the decrease in the water holding capacity of LE because of the protease contained in LE. In addition, it is thought that the addition of 7% DLE could prevent reduction of the product yield when producing rolled-dumplings.

3.2. pH and color

Table 2 shows the pH of the rolled-dumplings with different amounts of DLE. The pH of the rolled-dumplings before and after heating increased significantly as the content of DLE (pH 6.27 ± 0.03) increased ($p<0.05$). It is known that the initial pH of meat products is affected by additives, the pH of mushrooms undergoing the HAD process increases due to the loss of acid-related substances by heating (Çakmak et al., 2016; Ko and Yoo, 2018). It has also been reported that organic acids are decomposed by heat (Aktas and Yildiz., 2011). As a similar result, organic acid loss of *Stropharia rugoso-annulata* due to the HAD process was reported, and in this study, it is considered that the pH increased due to organic acid loss of LE by HAD

(Hu et al., 2020). Therefore, it is thought that the pH of the rolled-dumplings increased with the addition of DLE.

Before heating, the L^* value of the rolled-dumplings with different amounts of DLE (L^*: 53.33 ± 2.08, a^*: 5.77 ± 0.31, b^*: 14.20 ± 0.48) decreased significantly as DLE content increased (p<0.05). After heating, the L^* value was significantly lower for the group with added DLE than for the group with no DLE (p<0.05). Before and after heating, the a^* value was significantly higher for the rolled-dumplings with 9% DLE than for the congeners with no DLE. However, there was no significant difference between the a^* values for the samples with 7% DLE and no DLE (p<0.05). Before heating, the b^* value was significantly lower for the samples with DLE than for those without DLE (p<0.05). After heating, there was no significant difference in the b^* value of the various samples (p>0.05). The Maillard reaction, a non-enzymatic browning reaction, is a chemical reaction between the carbonyl group of reducing sugars and the amino group of free amino acids that produces melanoidin, which is brown (Murata, 2021). Chen et al (2021) reported that L^*, a^*, b^* decreased due to enzymatic browning and non-enzymatic Maillard reaction caused by HAD of LE. However, the increase in a^* observed with the addition of DLE is considered to have occurred because the initial redness of rolled-dumplings was lower than that of DLE. Based on these results, it seems that the color change of rolled-dumplings was influenced by the addition of DLE, which was browned by melanin generated during the HAD process.

3.3. TPA

Table 3 shows the TPA data for the rolled-dumplings with different levels of DLE addition. Consumers prefer tender, juicier sausages, while spherical meat products like meatballs are harder and more elastic (Huang et al., 2005). The hardness, gumminess, and chewiness increased significantly as the DLE addition level increased ($p<0.05$). The cohesiveness was significantly higher for the samples with DLE than for those without DLE ($p<0.05$). It is known that the texture of meat products is affected by several factors, such as the particle size and moisture content of the non-meat components (Younis et al., 2021). Cellulose, the main component of the cell wall of mushrooms, is replaced by lignin during heating and is lignified by chemical bonding with non-cellulose carbohydrates, which affects the texture (Donaldson, 2001; Yang et al., 2017). It has been reported that lignification by lignin increases the firmness of mushrooms (Jiang et al., 2010; Li et al., 2016). Furthermore, the texture properties of meat products are also known to be related to the gelation of myofibrillar protein and the structural binding of protein and water following the addition of dietary fiber (Kurt and Gençcelep., 2018; Zhuang et al., 2019). Therefore, it is considered that the added DLE influenced, and in fact changed, the textural properties of the rolled-dumplings.

3.4. E-nose

The results of e-nose analysis of the rolled-dumpling samples with different DLE contents are shown in Fig. 2 (A) and (B) as the PCA and mean bar graphs, respectively. The contribution rates of the first principal component (PC1; X-axis) and the second principal component (PC2; Y-axis) were 99.528% and 0.3073%, respectively. The difference caused by adding DLE to the rolled-dumplings was mainly confirmed through PC1. In the PCA plot, the samples with and without DLE were located at positive and negative values on the X-axis, respectively. Therefore, it was confirmed that DLE addition caused a difference in the flavor of the rolled-dumplings. The values were observed for the specific sensors (21.78, 22.76, 32.68, 34.37, 35.16, 39.58, 52.82) of the MXT-5 column (-1) and the specific sensors (19.26, 23.52, 25.36, 29.27, 30.36, 31.37, 41.19, 51.75) of the MXT-1701 column (-2). As the DLE content increased, the mean bar graphs showed a positive correlation for the 22.76-1, 39.58-1, 52.82-1, 23.52-2, 25.36-2, 29.27-2, 41.19-2, and 51.75-2 sensors. The representative compounds and flavors associated with each sensor are 22.76-1 (methanethiol: meaty, sulfurous), 39.58-1 (3-methylbutanal: malty, toasted), 52.82-1 (pyrazine: pungent, roasted hazelnuts), 23.52-2 (ethanol): pungent, sweet), 25.36-2, 29.27-2 (carbon disulfide: burnt, sulfurous), 41.19-2 (1-hydroxy-2-propanone: caramelized, sweet), 51.75-2 (toluene: caramelized, pungent). DLE forms a distinctive flavor due to the Maillard reaction induced by heating and amadori rearrangement occurring at the beginning of the browning reaction (Li et al., 2022). The flavor characteristics of the rolled-dumplings were affected by the compounds exhibiting the characteristic flavor of DLE. The 21.78-1, 32.68-1, 34.37-1, 35.16-1, 19.26-2, 30.36-2, and 31.37-2 sensors showed negative correlation. The content of compounds corresponding to 21.78-1 (trimethylamine: ammoniacal), 32.68-1, 30.36-2 (2-methylfuran: burnt, musty), 34.37-1 (acetic acid: acidic, sour), 35.16-1 (2-methyl-1-propanol: alcoholic, bitter), 19.26-2 (acetaldehyde: etheral), and 31.37-2 (ethyl acetate: acidic, etheral) was also thought to be decreased by DLE addition. DLE addition affects the flavor properties of the rolled-dumplings by increasing the positively acceptable odor compounds such as methanethiol and 3-methylbutanal and causing a relative decrease in the negatively acceptable odor compounds such as trimethylamine and acetic acid. These flavors are associated with the flavor compounds formed by the chemical reactions of DLE during the HAD process.

3.5. E-tongue

The results of e-tongue analysis of the rolled-dumplings with different DLE content are shown in Fig. 3 (A) and (B) as the radar chart and intensity scale bar chart, respectively. The sourness was ranked as 5.7 and 5.4 for the samples with 7% and 9% DLE, respectively, indicating lower strength than that of the sample without DLE, for which the sourness was ranked as 7.0. It seems that the higher pH due to the increase in the DLE content reduced the sour taste of the rolled-dumplings. Sourness is mainly determined by pH, and sourness can be predicted through pH measurement (Clement et al., 2020). The saltiness was ranked as 6.3 and 7.1 for the samples with 7% and 9% DLE, respectively, indicating higher saltiness than that of the sample without DLE (4.6). The umami taste was ranked as 6.0 and 6.9 for the samples with 7% and 9% DLE, respectively, which is higher than that of the sample without DLE (5.1). Edible mushrooms contain MSG-like amino acids (Asp, Glu) and 5'-nucleotides, which are umami factors. Umami contributes to the palatability of food, promotes food intake, acts as an inhibitor of bitterness which has a negative organoleptic effect, and is a saltiness enhancer (Kim et al., 2015; Myrdal Miller et al., 2014; Zhang et al., 2013; Zhu et al., 2022). The equivalent umami concentration of DLE at 60 ℃ has been reported to be 19.7 g MSG/100 g, and it is known that compounds such as free amino acids and 5′-nucleotides can be used as flavor enhancers in low-salt foods (Harada-Padermo et al., 2020; Yang et al., 2019). When ground beef steak and beef burgers were prepared using LE extract, the saltiness and umami taste were improved, similar to the results of this study (Dermiki et al., 2013; Mattar et al., 2018). Based on the results, the umami factor of LE extracted in the HAD process improved the saltiness and umami taste of the rolled-dumplings. Therefore, it is considered that with DLE addition, the amount of the organoleptic properties of meat products can be improved, as DLE acts as a saltiness and flavor enhancer.

3.6. Organoleptic evaluation

Table 4 shows the results of the organoleptic evaluation of the rolled-dumplings. The samples with DLE had significantly higher color values than those without DLE ($p<0.05$). The reduction in L^* for the rolled-dumplings due to DLE addition was positively perceived by consumers compared to that of the sample without DLE. On the other hand, because there was no significant difference in a^* for the samples with 7% DLE and no DLE, a^* for the rolled-dumplings does not seem to affect consumers' color acceptance. Meat products with high-fat content are known to have a brighter color than products with low-fat content, which may reflect the perception that consumers prefer products with a low-fat content when choosing products (Issanchou., 1996; Tobin et al., 2012). The sample with 7% DLE received the highest score in the flavor category, and that without DLE received the lowest score ($p<0.05$). As seen from the e-nose and e-tongue data, DLE addition may influence the tastes and flavors compared to those of the samples without DLE. Therefore, DLE can be used as an additive to increase consumer acceptance. Also, for the lowered flavor score of 9% DLE, Du et. (2021) explained that this was because too much mushroom flavor was created with increasing mushroom content. In the texture evaluation, the sample with 7% DLE received a significantly higher score than that without DLE ($p<0.05$). It was confirmed that the enhancement of the texture properties due to DLE addition contributed to improving the texture of the rolled-dumplings. The juiciness was evaluated as significantly higher for the samples with 7% DLE than for those with 9% DLE ($p<0.05$). The previous results show that the decrease in the moisture content according to the DLE addition was proportional to the cooking yield. The samples with 7% DLE received the most favorable evaluation in the off-flavor categories compared to those without DLE and with 9% DLE ($p<0.05$). Based on the fact that the samples with 9% DLE received a lower score in the flavor, juiciness, and off-flavor categories than the samples with 7% DLE, it is judged that excessive DLE addition acts as a foreign substance and adversely affects the organoleptic acceptance of consumers. However, adding DLE to rolled-dumplings had a higher flavor score than when it was not added, and it can be seen that consumers appreciate the contribution of flavor more in the overall acceptability category. In the overall acceptability category, the samples with DLE received significantly higher scores than those without DLE ($p<0.05$). Consumers perceive the organoleptic properties through the interaction of taste, tenderness, texture, and gravy (Novaković and Tomašević, 2017). Therefore, it is judged that the sample with DLE, which received higher scores than those without DLE in various categories, will receive higher scores in overall preference. When LE powder was added to Frankfurter sausage, high flavor and preference scores were obtained due to the improved organoleptic properties induced by flavor-enhancing substances (5′-GMP and lentihionine) and taste active compounds (MSG) (Seong et al., 2015). In addition, the ability of LE to improve the organoleptic properties of low-fat meatballs was reported, suggesting that the use of LE for flavor enhancement in the production of low-fat meatballs can increase consumer acceptance by improving the organoleptic properties (Ramle et al., 2021). The addition of DLE to rolled-dumplings may be positively accepted by consumers because the flavor of the dumplings is enhanced by flavor enhancers and flavoring ingredients in DLE. Moreover, 7% DLE can be set as the optimal addition ratio because the samples with this DLE content received the highest scores in all organoleptic evaluation categories.

4. Conclusions

The changes in the physicochemical and organoleptic properties of rolled-dumplings due to DLE addition were analyzed. The addition of DLE reduced the moisture content and L^*, while increasing the carbohydrate content, pH, a^*, texture properties of the rolled-dumplings. The cooking yield was reduced by 9% DLE addition, but was not affected by 7% DLE addition. The loss of acid-related substances and browning reactions caused by the HAD process decreased the pH and color change of the rolled-dumplings. DLE improved the texture properties of rolled- dumplings. E-nose and e-tongue analyses showed that the addition of DLE to rolled-dumplings increased the positively acceptable flavor compounds such as methanethiol (meaty, sulfurous), 3-methylbutanal (malty, toasted) and the saltiness and umami taste were also improved. In the organoleptic evaluation, the color change due to DLE addition resulted in a high color score for the rolled-dumplings. In addition, the difference in the flavor and taste induced by DLE had a positive effect on the flavor and off-flavor scores. Because of the changes in the texture properties of the rolled-dumplings, DLE also positively affected the texture. DLE addition to rolled-dumplings could receive a significantly positive overall evaluation. However, the addition of 9% DLE may have a negative effect on the organoleptic acceptance as it is perceived as a foreign substance. Therefore, DLE has the potential to be applied as a flavoring agent, flavor enhancer for rolled-dumplings. The addition of DLE to rolled-dumplings can improve the quality and organoleptic properties and cause a positive response in consumer acceptance.

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Table 1. Proximate composition of rolled-dumplings with various levels of hot-air dried *Lentinula Edodes* pileus (DLE)

Traits (%)	DLE (%)			
	Non	7	9	SEM
Moisture	64.26 ± 0.25[a]	59.50 ± 0.23[b]	58.34 ± 1.03[c]	1.107
Protein	14.98 ± 0.49	14.05 ± 1.34	13.11 ± 1.03	0.427
Fat	5.28 ± 0.85	5.30 ± 1.28	5.72 ± 1.35	0.348
Ash	1.99 ± 0.13	2.32 ± 0.18	2.43 ± 0.28	0.107
Carbohydrate	13.02 ± 1.44[b]	16.85 ± 0.60[a]	19.10 ± 0.45[a]	1.162

All values are mean ± SD.

[a-c] Mean in the same row with different letters are significantly different ($p<0.05$).

SEM: standard error of the mean (n=9).

Table 2. pH and color of rolled-dumplings with various levels of hot-air dried *Lentinula Edodes* pileus (DLE)

Traits			DLE (%)			
			Non	7	9	SEM
pH	Uncooked		5.82 ± 0.01^{c}	6.02 ± 0.02^{b}	6.05 ± 0.01^{a}	0.025
	Cooked		6.07 ± 0.01^{c}	6.10 ± 0.01^{b}	6.13 ± 0.01^{a}	0.006
Color	Uncooked	CIE L^*	64.63 ± 1.12^{a}	57.87 ± 2.43^{b}	54.75 ± 2.17^{c}	1.093
		CIE a^*	1.25 ± 0.48^{b}	1.67 ± 0.62^{ab}	2.23 ± 0.16^{a}	0.141
		CIE b^*	15.45 ± 0.96^{a}	13.02 ± 1.57^{b}	12.15 ± 0.80^{b}	0.425
	Cooked	CIE L^*	66.52 ± 2.03^{a}	60.97 ± 1.55^{b}	59.40 ± 1.06^{b}	1.072
		CIE a^*	1.73 ± 0.17^{b}	2.30 ± 0.44^{ab}	3.04 ± 0.94^{a}	0.228
		CIE b^*	12.78 ± 0.57	13.03 ± 0.43	13.62 ± 0.82	0.193

All values are mean ± SD.

$^{a-c}$ Mean in the same row with different letters are significantly different ($p<0.05$).

SEM: Standard error of the mean (n=9).

Table 3. Texture profile analysis of rolled-dumplings with various levels of hot-air dried *Lentinula Edodes* pileus (DLE)

Traits	DLE (%)			
	Non	7	9	SEM
Hardness (N)	30.19 ± 1.89^{c}	45.04 ± 2.18^{b}	52.14 ± 4.05^{a}	2.953
Springiness	0.91 ± 0.03	0.93 ± 0.01	0.94 ± 0.01	0.007
Gumminess (N)	13.48 ± 0.93^{c}	20.57 ± 1.94^{b}	25.68 ± 2.60^{a}	1.527
Chewiness (N)	11.98 ± 0.59^{c}	18.35 ± 0.86^{b}	23.52 ± 1.84^{a}	1.528
Cohesiveness	0.43 ± 0.02^{b}	0.50 ± 0.03^{a}	0.50 ± 0.01^{a}	0.012

All values are mean ± SD.

$^{a\text{-}c}$ Mean in the same row with different letters are significantly different ($p<0.05$).

SEM: standard error of the mean (n=9).

Table 4. Organoleptic evaluation of rolled-dumplings with various levels of hot-air dried *Lentinula Edodes* pileus (DLE)

Traits	DLE (%)			
	Non	7	9	SEM
Color	8.06 ± 0.78^{b}	9.44 ± 0.50^{a}	9.19 ± 0.65^{a}	0.178
Flavor	7.63 ± 0.52^{c}	9.31 ± 0.59^{a}	8.69 ± 0.59^{b}	0.183
Texture	8.13 ± 0.64^{b}	8.94 ± 0.56^{a}	8.63 ± 0.95^{ab}	0.160
Juiciness	8.88 ± 0.23^{a}	8.69 ± 0.46^{a}	8.00 ± 0.71^{b}	0.126
Off-flavor	8.00 ± 0.76^{b}	8.94 ± 0.78^{a}	8.13 ± 0.64^{b}	0.166
Overall acceptability	7.88 ± 0.64^{b}	9.19 ± 0.53^{a}	8.69 ± 0.59^{a}	0.161

All values are mean ± SD.

$^{a\text{-}c}$ Mean in the same row with different letters are significantly different ($p<0.05$).

Color, flavor, texture, juiciness, Overall acceptability (10=extremely good or desirable, 1=extremely bad or undesirable); Off-flavor (10=extremely not felt, 1=extremely felt)

SEM: standard error of the mean (n=9).

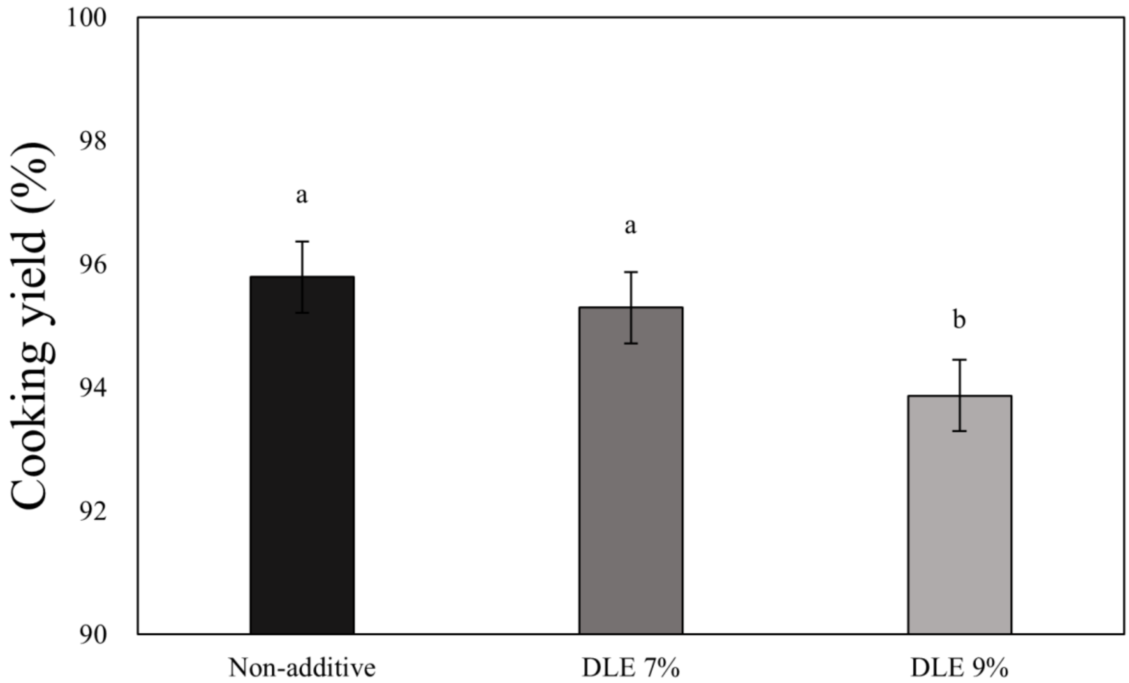

Fig. 1. Cooking yield of rolled-dumplings with various levels of hot-air dried *Lentinula Edodes* pileus (DLE). [a, b] Mean in the same bars with different letters are significantly different ($p<0.05$).

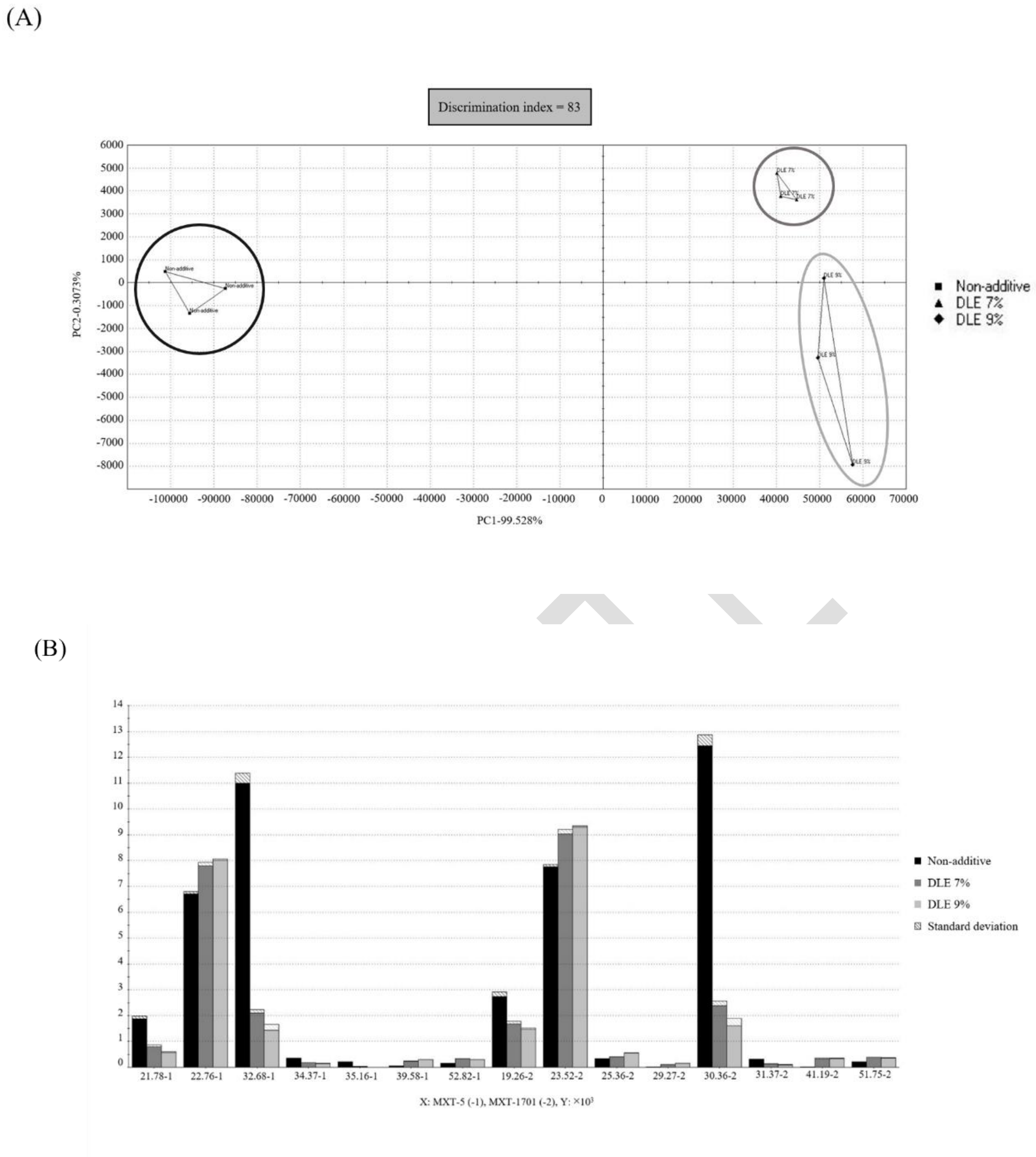

Fig. 2. (A) Principal component analysis score plots of rolled-dumplings with various levels of hot-air dried *Lentinula Edodes* pileus (DLE) using flash gas chromatography electronic nose. (B) Mean bar graphs of selected main peak area used as raw data in chromatogram representing main chemical compounds of rolled-dumplings with various levels of DLE using flash gas chromatography electronic nose. Mean bar graphs X-axis: variables (sensors), -1 (MXT-5), -2 (MXT-1701); Mean bar graphs Y-axis: abundance, size ($\times 10^3$).

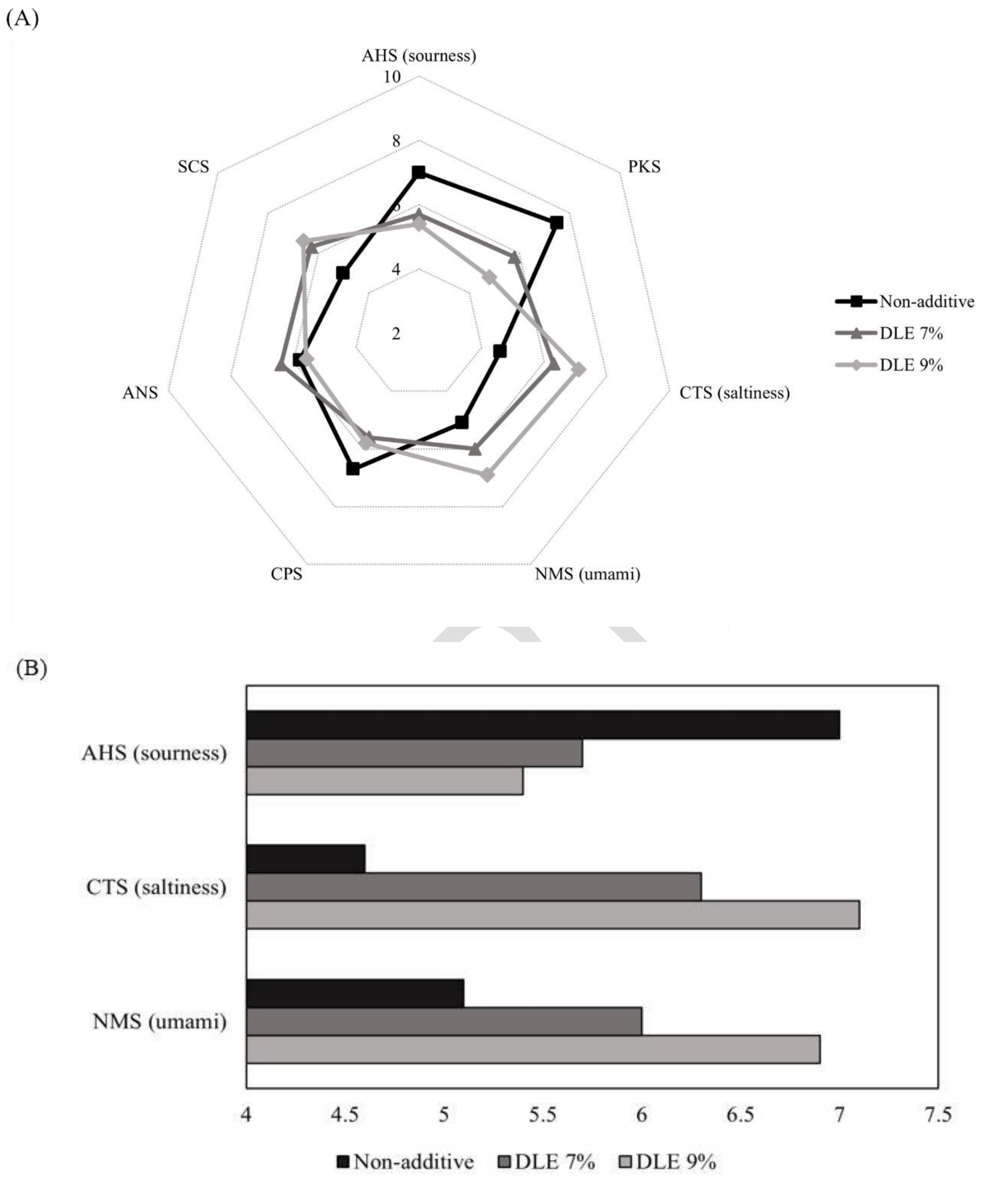

Fig. 3. (A) Intensity comparison score radar chart of rolled-dumplings with various levels of hot-air dried *Lentinula Edodes* pileus (DLE) using taste sensors electronic tongue. (B) Intensity scale score bar chart of rolled-dumplings with various levels of DLE using taste sensors electronic tongue. CTS: saltiness; NMS: umami; AHS: sourness; PKS, ANS: auxiliary sensor; SCS, CPS: standard sensor.