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# Descriptive Analysis of Seven Leguminous Plants in Korea

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**ABSTRACT:** Legumes are dicotyledonous plants, and they represent the third-largest plant family seeds distributed globally. This study aimed to develop a lexicon for seven well-known legumes: kidney bean, mung bean, chickpea, green kernel black bean, black bean, soybean, and red bean. A sensory lexicon describing the aroma characteristics of legumes was developed, and the intensity of each aroma attribute was evaluated using a 15-point universal scale in Spectrum$^{TM}$. Nine aroma terms were developed: boiled egg yolk, bean sprout, chicken breast, boiled chestnut, soymilk, green bean, raw peanut shell, soil odor, and mango. The lexicon identified nine descriptions for the sensory characteristics of legumes. Kidney bean, mung bean, and red bean had high green bean, bean sprout, and soil odor aromas, whereas soybean, green kernel black bean, black bean, and chickpea had strong boiled egg yolk, boiled chestnut, and chicken breast aromas. These results can aid food product developers with flavor optimization in product formulation.

**Keywords:** aroma, bean, descriptive analysis, legumes, sensory analysis

## INTRODUCTION

Legumes are dicotyledonous plants, representing the third-largest plant family seeds distributed worldwide. Legumes are typically used for feed, food, industrial and medicinal compounds, and fiber (Somers et al., 2003). Compared with cereals, legumes are a more nutritious food source (Duranti, 2006), mainly because they provide healthy vegetable protein, especially lysine (Gętek et al., 2014), and minerals such as calcium, potassium, magnesium, iron, and zinc (Madar and Stark, 2002). Traditionally, Koreans have used legumes, such as soybeans, red beans, mung beans, and kidney beans, rather than red meat, as a protein source (Kim et al., 2016). Each bean product has unique flavor characteristics, and consumers have different preferences.

Because of the unique taste and flavor characteristics of legumes, studies have documented the flavor differences between legumes, including kidney beans (Mkanda et al., 2007), red kidney beans (Mishra et al., 2017), common beans with irradiation treatment (Armelim et al., 2006), soybeans (Da Silva et al., 2012), soybean sprouts (Troszyńska et al., 2007), mung bean sprouts (Wołejszo et al., 2007), and puffed desi chickpeas (Mukhopadhyay et al., 2018). Additionally, two of the most studied products made by processing legumes are soy milk (Torres-Penaranda et al., 1998; Torres-Penaranda and Reitmeier, 2001; Navicha et al., 2018) and tofu (Torres-Penaranda et al., 1998; Chung et al., 2008; Kamizake et al., 2018). Table 1 lists previously developed sensory lexicons for beans and bean-processed products. A previous study on the descriptive analysis of beans had investigated changes in the sensory attributes of common beans according to gamma radiation (Armelim et al., 2006). In their study, 21 descriptive sensory terms (sensory lexicons) describing the sensory characteristics of common beans were reported (Armelim et al., 2006). A previously conducted descriptive analysis of six kidney bean varieties reported 21 terms describing aroma, flavor, appearance, texture, and mouthfeel attributes, and among these terms, cooked bean flavor, sweet, and soft texture were identified as drivers of consumer likings of kidney beans (Mkanda et al., 2007). Another study on aroma changes of red kidney beans during cooking reported five descriptive terms to describe the aroma characteristics of red kidney beans. Fourteen descriptors were developed using a sensory trained panel regarding soybeans, including grain size, grain shape, cream color grain, hilum color, rancid, cooked bean, sweetness, rancid sweet, and bitter, astringent, umami, and hardness textures. Their work investigated the different sensory properties associated with soybean cultivars using a trained panel as well as an electronic

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**Table 1.** Summary of previously published sensory analyses of legumes and legume-containing products

| Reference | Subject studied | Sensory lexicon |
|---|---|---|
| Torres-Penaranda et al. (1998) | Soymilk and tofu | Flavor: cooked beany aroma, cooked beany flavor, milky flavor, wheat flavor, astringency<br>Viscosity: thickness<br>Texture: chalkiness, aftertaste, hardness<br>Color: darkness, yellowness |
| Torres-Penaranda and Reitmeier (2001) | Soymilk | Aroma: raw as hexanal, starch as flour, sweet as dairy caramelized<br>Flavor: raw as hexanal, grassy, sweet as green floral, painty, sweet as dairy caramelized, metallic, bitter<br>Mouthfeel: astringent, mouth coating |
| Armelim et al. (2006) | Common bean (*Phaseolus vulgaris* L.) | Appearance: color, brightness, uniformity, broken, broth viscosity<br>Aroma: characteristic, new, sweetish, burned, metallic, warmed up<br>Flavor: burned, bitter, sweetish, fresh, metallic, warmed up<br>Texture: hardness, sandy, juiciness |
| Mkanda et al. (2007) | Dry beans (*Phaseolus vulgaris*) | Appearance: splitting, broth thickness, seed-coat peeling<br>Aroma: raw bean aroma, cooked bean aroma<br>Flavor: raw bean flavor, cooked bean flavor, sweetness, saltiness, nutty flavor, bitterness<br>Texture/mouthfeel: softness, mushiness, soapy feeling, metallic feeling, seed-coat residues |
| Troszyńka et al. (2007) | Soybean sprouts | Aroma: beany, rancid, grassy<br>Taste: beany, green, fresh, rancid, bitter, astringent, pungent, grassy<br>Texture: juiciness, fibrousness |
| Wołejszo et al. (2007) | Mung bean sprouts | Aroma: beany, grassy<br>Taste: green, beany, fresh, bitter, astringent, pungent, pea-pod, grassy<br>Texture: flourness, juiciness, fibrousness |
| Chung et al. (2008) | Tofu | Appearance: whiteness, yellowness, roughness, moistness<br>Odor/aroma: green, raw soy, dirty socks, cooked bean, briny, chlorine<br>Flavor/taste: cooked bean, raw bean, salty, sweet, umami, bitter<br>Texture/mouthfeel: springiness, hardness, easy to cut, stickiness, silkiness, easy to swallow, moistness<br>Aftertaste: bitter, salty, cooked bean, astringent |
| Da Silva et al. (2012) | Soybeans | Appearance: grain size, grain shape, cream color grain, hilum color<br>Aroma: rancid, cooked bean, sweetness<br>Flavor: cooked bean, rancid, sweet, bitter, astringent, umami<br>Texture: hardness |
| Mishra et al. (2017) | Red kidney beans (*Phaseolus vulgaris*) | Smoky, sulfury, red kidney beans-like, earthy/raw potato, boiled potato |
| Mukhopadhyay et al. (2018) | Puffed desi chickpea | Appearance: roundness, size, yellow, brown, luster<br>Aroma: roastiness, nuttiness, spiciness<br>Texture: finger feel<br>Mouthfeel: smoothness, hardness<br>Taste: spicy, roasted, hot, nutty, savory<br>Aftertaste: bitterness, pepper, persistence |
| Kamizake et al. (2018) | Tofu | Appearance: gray color, color uniformity, brightness, roughness, cohesion<br>Aroma: sweet, fermented<br>Flavor: sweet, bitter, astringent, rancid, fermented<br>Texture: firmness, fracturability, elasticity, residual adherence |
| Navicha et al. (2018) | Soymilk | Color intensity, sweet aromatics, beany, roasted, viscosity, sweetness, bitterness, salty, sour |

tongue. Studies on soy milk were well-documented, and 10 sensory lexicons were developed to describe the sensory characteristics of soy milk according to its raw material (type of soybeans and the origin of soybeans). In a follow-up study from the same research team, a total of 12 sensory lexicons were derived from soy milk (Torres-Penaranda and Reitmeier, 2001). In another descriptive analysis of soy milk, nine descriptors were developed for the evaluation of soy milk with differential soybean roasting conditions, and they reported significant differences between soymilk products in all sensory attributes except for "bitter" and "salty" taste-related attributes (Navicha et al., 2018). Tofu, which is another soybean-processed food, has also been well studied: 27 lexicons were developed for the evaluation of seven tofu commercially available samples, and they reported differences in tofu sensory characteristics according to the type of beans, the brand, and the processing method (Chung et al., 2008). In another tofu study, researchers investigated the effect of soybean aging conditions on sensory characteristics. In this study, a total of 16 descriptive terms were developed and the analysis showed that tofu made from aging soybeans had a less appealing appearance, aroma, flavor, and texture (Kamizake et al., 2018).

To our knowledge, a sensory lexicon to wholly describe the aroma characteristics of various legume products has not been sufficiently studied. Understanding the unique aroma characteristics of each bean in the legume family is critical for food development. Thus, the objective of this study was to develop a lexicon for seven well-known legumes: kidney bean, mung bean, chickpea, green kernel black bean, black bean, soybean, and red bean.

## MATERIALS AND METHODS

### Sample preparation

Seven legumes—kidney bean (L1; Glory Food, Seoul, Korea), mung bean (L2; Glory Food), soybean (L3; Glory Food), red bean (L4; Glory Food), green kernel black bean (L5; Glory Food), black bean (L6; Glory Food), and chickpea (L7; Dongsanwon, Bucheon, Korea)— were selected. These legumes were selected based on their availability from the same supplier. Although taxonomic species of each legume were slightly different in these samples, this study focused on the highly consumed legumes in Korea and those that are available from the same supplier. The aroma characteristics within the same legume species can be influenced by various factors, from preharvest to postharvest processing conditions. Although it is almost impossible to control the preharvest conditions that may affect the aroma characteristics of the samples, this study obtained samples from the same supplier so that the postharvest condition of the samples was controlled. All legumes were purchased from a local grocery store near Jeonbuk National University in Jeonju, Korea. To prepare each legume for descriptive analysis, 25 g of each legume sample (excluding L2) was soaked in water for 24 h before cooking. Then, all the samples were individually added to 500 mL of water and boiled for 30 min over low heat, except for L2. Based on preliminary experiments on developing cooking methods for each bean sample, L2 did not require a soaking process before boiling, and the boiling time was slightly different: L2 was added to 300 mL of water and boiled for 15 min over low heat. After the legumes were boiled, the water was removed, and the legumes were immediately cooled to room temperature (25°C). A 4 g sample of each boiled legume was placed in 50 mL white, opaque cups labeled with three-digit random numbers. This study was approved by the Institutional Review Board (IRB) of Jeonbuk National University (IRB no. 2020-10-005-001, JBNU), and informed consent form was collected from each participant.

### Descriptive analysis

A descriptive analysis of the legumes was conducted using a highly trained panel consisting of four women and two men aged 23 to 41 years. Each panelist had more than 500 h of prior experience in the sensory analysis of legume-related products using the Spectrum™ method (Meilgaard et al., 1999). Before the evaluation, the panelists underwent an 18-h training session to develop the sensory lexicon for the legume samples. Sensory references for each sensory lexicon term were provided to minimize the variation of expressions between panelists. On the evaluation day, panelists received a 50-mL white, opaque cup labeled with a three-digit random number containing one type of legume. Panelists were asked to evaluate the aroma attributes in quadruplicate, and the order of sample presentation was randomly assigned according to a Latin-square design. To evaluate odor-related characteristics, panelists were asked to open the lid of the sample container and sniff the product three times. A 2-min rest was enforced between sample evaluations to minimize any carryover effect. The panelists recorded their intensity ratings on a paper ballot using the 15-point universal scale in Spectrum™. Panelists were invited for an appreciation dinner as compensation for participation in the descriptive analysis.

### Statistical analysis

The data analysis was conducted using XLSTAT (ver. 2020, Addinsoft, Paris, France). Analysis of variance was performed, followed by Duncan's multiple range test to determine sample differences at an $\alpha$ level of 0.05. Principal component analysis (PCA) was conducted to determine where each sample was located on the sensory characteristics map and group the legumes according to flavor similarity.

## RESULTS

Table 2 shows the lexicon for the sensory characteristics of the legumes. The lexicon developed in this study included boiled egg yolk, bean sprout, boiled chestnut, chicken breast, green bean, mango, soymilk, raw peanut shell, and soil odor. Previous descriptive analysis studies of leguminous plants have reported the terms sweetish, burned, metallic, sulfury, raw bean/cooked bean aroma, green, and earthy. Our study showed similarities to other studies concerning the raw bean aroma, green, and earthy terms but showed differences regarding the sweetish, burned, metallic, and sulfury terms (Table 1). In previous descriptive analyses of L1, terms such as metallic, raw bean aroma, cooked bean aroma, and earthy/raw potato were used. The descriptors bean sprout and raw peanut shell that were used in our study were characterized sim-

**Table 2.** Lexicon developed for descriptive sensory analysis

| Descriptor | Definition | Reference |
|---|---|---|
| Boiled egg yolk | Characteristic aromatics associated with cooked egg yolk | Hard-boiled egg yolk |
| Bean sprout | Characteristic aromatics associated with bean sprout | Bean sprout (raw) |
| Boiled chestnut | Characteristic aromatics associated with cooked chestnut | Boiled chestnut (Jeonju, Korea) |
| Chicken breast | Characteristic aromatics associated with chicken breast | Unseasoned chicken breast (RTE) (Harim®, Seoul, Korea) |
| Green bean | Characteristic aromatics associated with green bean | Canned green bean (Del Monte Foods, Inc., Walnut Creek, CA, USA) |
| Mango | Characteristic aromatics associated with mango | Frozen mango (Wellfarm, Co., Ltd., Eumseong, Korea) |
| Soymilk | Characteristic aromatics associated with soymilk | Soymilk (Maeil Dairies Co., Ltd., Seoul, Korea) |
| Raw peanut shell | Characteristic aromatics associated with peanut shell | Raw peanut shell (Jeonju, Korea) |
| Soil | Characteristic aromatics associated with soil | Wet soil |

ilarly to the raw bean aroma in a previous study; furthermore, boiled chestnut was similar to the cooked bean aroma, and the soil odor attribute was similar to earthy/raw potato (Armelim et al., 2006; Mkanda et al., 2007; Mishra et al., 2017). Previous analyses of L3 used descriptors such as cooked bean, beany, green, rancid, and grassy. The descriptors of cooked bean and beany had characteristics similar to boiled chestnut in our study, and green and grassy terms had characteristics similar to green bean in our study (Troszyńska et al., 2007; Da Silva et al., 2012). A previous descriptive analysis of L2 developed terms such as beany, grassy, green, fresh, and pea-pod. The term beany had characteristics similar to boiled chestnut in our study, and the terms grassy, green, and pea-pod had characteristics similar to green bean in our study (Wołejszo et al., 2007).

Table 3 presents the results of the descriptive sensory analysis of seven legumes. Among the nine attributes describing aroma characteristics of legumes, eight attributes (boiled egg yolk, bean sprout, boiled chestnut, chicken breast, green bean, mango, soymilk, and soil odor) exhibited significant differences across samples ($P$<0.05), except for the raw peanut shell aromatic ($P$>0.05). The aroma intensity for boiled egg yolk ranged from 0.07 to 2.10 in all samples. The boiled egg yolk attribute was significantly higher in L3, L5, L6, and L7 than aroma intensities found in other samples ($P$<0.05). The aroma intensity for the bean sprout was found in less than 1 on a 15-pt universal scale and was significantly higher in L2 than in other samples ($P$<0.05). The boiled chestnut attribute was only found in L3, L5, L6, and L7. The chicken breast attribute ranged between 0.53 and 2.35 in all legumes, and it was significantly higher in L5 followed by L3 than in other samples ($P$<0.05). The green bean attribute existed only in L1, L2, and L4, and the aroma intensity of the green bean was significantly higher in L1 and L4 than in L2 ($P$<0.05). The mango attribute was found in all samples except L1 and L7, whereas the aroma intensities of mango found in these samples were lower than 1.0 on a 15-pt universal scale. The aroma intensity of soymilk ranged from 0.05 to 1.81 and was found in all legume samples. The aroma intensity of soymilk was significantly higher in L3, L5, and L6 than what was rated in other samples ($P$<0.05). The intensity of soil odor was the highest (2.71) for L4, followed by L1 (2.15) ($P$<0.05).

Fig. 1 shows the PCA biplot of the descriptive analysis result for the seven legume samples. This biplot explain-

**Table 3.** Descriptive sensory analysis results of legumes

| Descriptor | L1 | L2 | L3 | L4 | L5 | L6 | L7 | $P$-value |
|---|---|---|---|---|---|---|---|---|
| Boiled egg yolk | $0.18^{b}$ | $0.07^{b}$ | $1.89^{a}$ | $0.13^{b}$ | $2.03^{a}$ | $2.10^{a}$ | $2.01^{a}$ | <0.0001 |
| Bean sprout | $0.50^{b}$ | $0.94^{a}$ | $0.02^{c}$ | $0.50^{b}$ | $0.06^{c}$ | $0.23^{c}$ | $0.08^{c}$ | <0.0001 |
| Boiled chestnut | $0.00^{b}$ | $0.00^{b}$ | $1.93^{a}$ | $0.00^{b}$ | $2.03^{a}$ | $1.84^{a}$ | $1.66^{a}$ | <0.0001 |
| Chicken breast | $0.66^{d}$ | $0.85^{d}$ | $2.15^{ab}$ | $0.53^{d}$ | $2.35^{a}$ | $1.86^{bc}$ | $1.60^{c}$ | <0.0001 |
| Green bean | $2.16^{a}$ | $1.29^{b}$ | $0.00^{c}$ | $2.08^{a}$ | $0.00^{c}$ | $0.00^{c}$ | $0.00^{c}$ | <0.0001 |
| Mango | $0.00^{b}$ | $0.08^{b}$ | $0.84^{a}$ | $0.10^{b}$ | $0.53^{a}$ | $0.58^{a}$ | $0.00^{b}$ | <0.0001 |
| Soymilk | $0.22^{c}$ | $0.11^{c}$ | $1.81^{a}$ | $0.05^{c}$ | $1.77^{a}$ | $1.52^{a}$ | $0.74^{b}$ | <0.0001 |
| Raw peanut shell | $1.02^{ns}$ | 0.89 | 0.71 | 0.84 | 0.62 | 1.00 | 0.70 | 0.316 |
| Soil odor | $2.15^{b}$ | $1.43^{c}$ | $0.00^{d}$ | $2.71^{a}$ | $0.00^{d}$ | $0.04^{d}$ | $0.04^{d}$ | <0.0001 |

Numbers represent the mean values of triplicate analysis of aroma characteristics of legumes using a highly trained panel consisting of six panelists.
Means in a row with different letters (a-d) are significantly different ($P$<0.05).
$^{ns}$Not significant.
L1, kidney bean; L2, mung bean; L3, soybean L4, red bean; L5, green kernel black bean; L6, black bean; L7, chickpea.

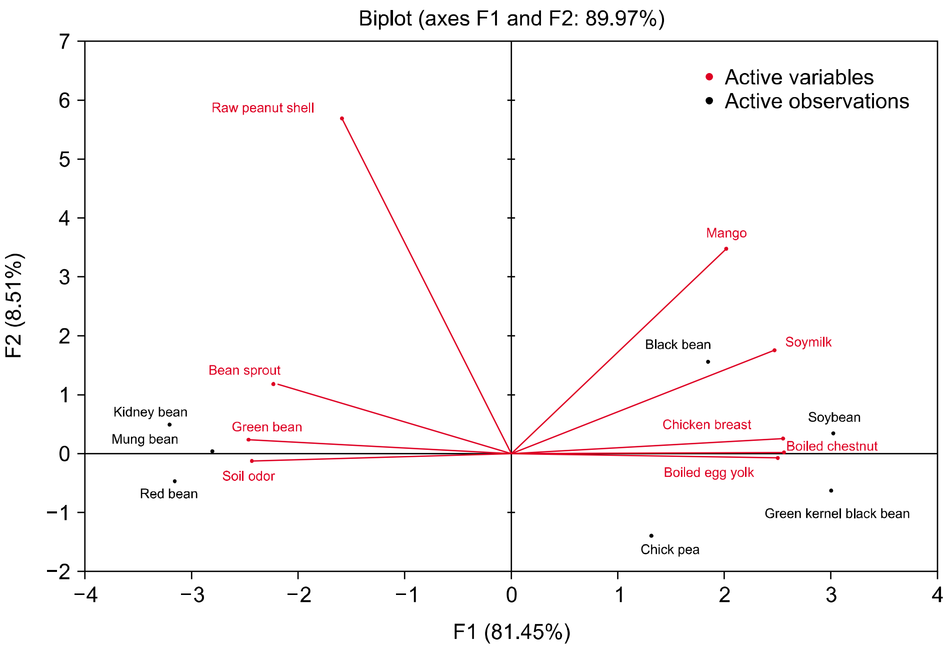


**Fig. 1.** Principal component analysis of aroma characteristics of the seven legumes. F1, primary axes explaining 81.45% of dataset; F2, secondary axes explaining 8.51% of dataset.

ed 89.96% of the total variation. F1 is the primary axis and explains 81.45% of the total variability. PCA results revealed two groups of legumes according to their aromatic (dis)similarities. Legume samples in Group 1 included L1, L2, and L4, and samples in Group 1 shared similar aroma characteristics, such as bean sprout, green bean, and soil. Samples belonging to Group 2 included L3, L5, L6, and L7 and were characterized by boiled egg yolk, chicken breast, boiled chestnut, soymilk, and mango aromatics.

## DISCUSSION

A previous study of kidney beans' sensory attributes demonstrated that cooked bean aroma is one of the characteristic aromas in kidney beans (Armelim et al., 2006; Mkanda et al., 2007). Unlike previous studies, this study showed that green bean and soil odor attributes were the highest intensity among the aroma characteristics of the kidney bean. A previous study of soybean descriptive analysis reported that rancid, cooked beans, and sweet aroma are the characteristic aromas of soybeans. However, this study reported that chicken breast, boiled chestnut, boiled egg yolk, and soymilk aroma were the distinctive aromatics of soybean compared with other legumes. According to previous descriptive analysis studies of soybean-processed products, such as soymilk and tofu, made by processing soybean, terms such as cooked bean, raw as hexanal, beany, cooked bean, green, raw soy, sweet, and roasted were used (Torres-Penaranda et al., 1998; Torres-Penaranda and Reitmeier, 2001; Navicha et al., 2018). These terms may have the same aromatics described in this study, such as boiled chestnut, green bean, and mango aromatics.

Mung bean sprouts had the aroma attributes of beany and grassy, similar to bean sprouts and green beans used in this study (Wołejszo et al., 2007). This is the first descriptive analysis study for the mung bean, red bean, green kernel black bean, black bean, and chickpea. Previous studies have shown that compounds such as hexanal, octanal, phenylacetaldehyde, (2E)-2-nonen-1-ol, tetramethylpyrazine, isophorone, hexanol, 2,6-dimethylpyrazine, (E)-3-hepten-2-one, limonene, 2-ethyl-1-hexanol, (E)-2-octenal, decanal, cumin aldehyde, and geranyl acetone represent green descriptors for legumes (Attar et al., 2017; Mishra et al., 2017; Bi et al., 2021). Hexanal is a significant aldehyde found in beans, producing "green/grassy" aromatics (Del Rosario et al., 1984; Oomah et al., 2007). Compounds such as 3-furanmethanol, 2-ethyl-6-methylpyrazine, 1-octen-3-ol, trimethylpyrazine, thymol, 2-ethyl-3-methylpyrazine, and 3-isopropyl-2-methoxypyrazine provide earthy aroma characteristics in legumes (Hinterholzer et al., 1998; Mishra et al., 2017; Bi et al., 2021). Another study reported that cooked legumes' green and earthy odor characteristics may be attributed to enzymes, nonenzymes, and chemical reactions induced during heat processing. Because these compounds, representing green and earthy aromas, are commonly found in L1, L2, and L4 (Hinterholzer et al., 1998; Lee and Shibamoto, 2000; Oomah et al., 2007; Ma et al., 2016; Attar et al., 2017; Mishra et al., 2017; Chigwedere et al., 2019; Mishra et al., 2019; Bi et al., 2021), expectedly, that lexicons such as green bean and soil odor would be strongly exhibited in legumes from Group 1.

The descriptors of beans often include terms like nutty, sulfur, or stone fruit (Young et al., 2000; Krinsky, 2005; Wszelaki et al., 2005). Compounds such as 2-pentylfuran;

benzaldehyde; pyrrole; (E)-2-butanal; (E,E)-2,4-hexadiene; octanal; (E,E)-2,4-heptadienal; 2-octenal; (E,E)-2,4-nonadienal; decanal; 2,5-diethylpyrazine; and (E,E)-3,5-octendian-2-one have been reported as compounds that represent a nutty aroma (Szczygiel et al., 2017; Kaczmarska et al., 2018; Cai et al., 2021). Additionally, it has been reported that dimethyl trisulfide represents the meaty/metallic/sulfur descriptor, 2-acetylthiophene represents the sulfurous/nutty descriptor, and 2,3-diethyl-5-methylpyrazine represents the nutty/meaty descriptor (Kaczmarska et al., 2018; Cai et al., 2021). Finally, 2-pentylfuran, propanal, octanal, and 2-heptanone are compounds that represent a fruity aroma (Szczygiel et al., 2017; Cai et al., 2021). The compounds suggesting a nutty, sulfur, or stone fruit aroma are also commonly found in legumes from Group 2, which includes L3 and L6 (Kato et al., 1981; Ha et al., 1992; Torres-Penaranda et al., 1998; Lee and Shibamoto, 2000; Solina et al., 2005; Wu et al., 2009; Szczygiel et al., 2017; Kaczmarska et al., 2018; Cai et al., 2021). Hence, boiled chestnut, soymilk, and mango attributes are strongly exhibited in legumes from Group 2.

This study documented a descriptive sensory analysis of seven leguminous plants in Korea. Nine lexicons were developed, and seven legumes were grouped according to sensory characteristics determined by the descriptive analysis results. Legumes in Group 1 (kidney bean, mung bean, and red bean) had higher bean sprout, green bean, and soil odor aromatics. Legumes in Group 2 (soybean, green kernel black bean, black bean, and chickpea) were characterized as having boiled egg yolk, chicken breast, boiled chestnut, soymilk, and mango aromatics. The findings from this work can assist food product developers who use legumes and bean products for flavor optimization in product formulation. The results from this study suggest that soybean, green kernel black bean, black bean, and chickpea have a strong protein-related aroma, such as soy milk, chicken breast, and boiled egg yolk, and these legumes may be utilized as an ingredient for alternative meat development to enhance consumer satisfaction.

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## AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

## AUTHOR CONTRIBUTIONS

HO contributed to the manuscript preparation, data collection, and drafting of the manuscript; YJ contributed to the data collection and data analysis and manuscript drafting; MKK contributed to the data analysis and interpretation and manuscript write-up. All authors have read and agreed to the published version of the manuscript.

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