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Development of Odor Lexicons for Black Pepper Grown in Some Provinces in Vietnam

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Abstract

Pepper (Piper nigrum L.) is a major crop in Vietnam, serving as a primary export commodity and contributing significantly to the country's economic value. Despite being the world's leading producer and exporter of pepper, its production still faces numerous limitations, instability, and lacks sustainability, partly attributed to poor quality management, absence of branding, food adulteration, etc. Therefore, the aim of this study is to develop a lexicon of odor descriptors contributing to the identification of characteristic properties of pepper from different growing regions, evaluating the quality of pepper, and constructing the brand attributes of Vietnamese pepper. A panel of 10 individuals, selected and screened, participated in the process of constructing the lexicon of odor descriptors. Through three sessions of term reduction and two group discussion sessions on definitions and references, a list comprising 11 odor descriptors was condensed from an initial list of 33 terms. The final lexicon consists of 11 odor characteristic descriptions of pepper, each accompanied by a definition and reference agreed upon by the entire panel. This lexicon demonstrates the ability to differentiate pepper samples from various growing regions. Additionally, throughout the lexicon development process, the panel also exhibited significant improvements in the ability to recognize and employ terminology to describe the odor characteristics of pepper.

Keywords: *Piper nigrum L.*, black pepper, odor, lexicons development.

1. Introduction

Pepper is a major crop and a key export commodity for Vietnam, generating significant economic value and contributing to the growth of the national, regional, and local economies. Vietnam has maintained its position as the world's largest producer and exporter of pepper since 2001. Vietnam's pepper production accounts for over 40% of global production and nearly 60% of the global pepper export market. Notably, 95% of Vietnam's pepper output is destined for export, while the remaining 5% is consumed domestically (according to General Statistics Office of Vietnam). Despite holding the top position globally, pepper production in Vietnam faces several challenges, including instability, lack of sustainability, and quality management issues. These limitations are partly attributed to factors such as the absence of a strong brand identity and food fraud [1, 2].

With Vietnamese pepper reaching over 110 countries worldwide, fierce competition in terms of price and quality has emerged from other pepper-producing nations. Against this backdrop, asserting the quality and value of Vietnamese pepper in the international market is of paramount importance.

Essential oil plays a crucial role in determining the quality of black peppercorns. Researchers have documented significant variations in the chemical composition of black pepper essential oil, attributed to factors such as cultivar differences, geographical origin, raw material maturation stage, oil extraction processes, identification methods, and preparation method [3]. Over 80 components have been identified in black pepper essential oil, with key constituents including monoterpene hydrocarbons and oxygenated monoterpenoids, sesquiterpene hydrocarbons and oxygenated sesquiterpenes, and phenolic compounds [4]. The major compounds found in black pepper are germacrene D (11.01%), limonene (10.26%), β-pinene (10.02%), α-phellandrene (8.56%), β-caryophyllene (7.29%), α-pinen (6.40%), and cis-β-ocimene (3.19%). The primary contributors to the characteristic odor of black pepper are believed to be the following compounds: sabinene, β-pinene, α-phellandrene, δ-carene, β-phellandrene, limonene, isoborneol, β-caryophyllene, α-guaiene, α-humulene, sarisan, germacrene D, elemicin, calamenene, caryophyllene alcohol, isoelemicin, T-muurolol, cubenol, and bulnesol [5].

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These compounds, each with unique characteristics and thresholds, contribute to the multifaceted odor profile that distinguishes black pepper from other spices. However, to truly capture the essence of black pepper's odor, seven key compounds stand out: α-pinene, β-pinene, δ-3-carene, limonene, β-myrcene, linalool, and β-caryophyllene [6]. δ-3-carene, a characteristic component of black pepper, imparts spicy and refined-limonene-like notes. Limonene, with its citrus-like character, brings forth mild lemon and orange notes. β-caryophyllene contributes a spicy dimension to the odor, while α-pinene adds a sharp, pine-needle-like quality. β-pinen introduces a blend of spicy and dry-woody notes, and β-myrcene lends a touch of sweetness and balsamic undertones. Linalool, with its delicate floral essence, completes the symphony with a touch of freshness.

The complex odor of black pepper has been the subject of extensive research, leading to the development of odor models and descriptors that capture the multifaceted sensory characteristics of this culinary staple. Jagella and Grosch (1999) proposed an odor model for black pepper based on the quantification of 19 odor-active compounds using odor extract dilution analysis (AEDA), odor extract concentration analysis (AECA), and gas chromatography/olfactometry of headspace samples (GCOH) [7-9]. Their findings revealed that (±)-linalool, (+)-α-phellandrene, (-)-limonene, myrcene, (-)-α-pinene, 3-methylbutanal, and methylpropanal were the most potent odor-active compounds in black pepper. Additionally, 2-isopropyl-3-methoxypyrazine and 2,3-diethyl-5-methylpyrazine were identified as key odorants contributing to the musty odor of black pepper samples [7]. Govindarajan *et al*. developed a panel to assess the odor quality of pepper cultivars and commercial types [10]. Utilizing Harper's terminology to initially describe the odors of pepper oil fractions separated on alumina columns, panelists were selected and familiarized with the odor components of black pepper. Odor descriptions recorded by at least one-third of the panel were compiled. Subsequently, the terms used by at least one-third of the panel were selected, and through roundtable discussions, the panel was trained to achieve a unified understanding of the terms. The growing interest in spices has spurred the development of an updated herb and dried spice flavor wheel, the original of which was created at McCormick and Company, Inc. (McCormick) in the mid-1990s [11]. The new version of the McCormick Spice Wheel (MSW) draws upon terminology developed at McCormick, encompassing 17 categories and 56 attributes, with over 10 spices selected, including black pepper, cinnamon, cloves, dill, ginger, oregano, paprika, rosemary, thyme, and turmeric.

The study aimed to develop a list of descriptors for the odor of Vietnamese black pepper, from different growing regions. To achieve this goal, a sensory panel was carefully selected and tasked with creating a descriptive terminology list. This process involved sample evaluation, panel discussions, term refinement, definition construction, and reference selection. Descriptive terms need to ensure discrimination criteria, be non-redundant, be measured by a scale, singular, unambiguous, precise and reliable, easy to reference. The results of this study play an important role in evaluating the quality of Vietnamese pepper, especially its typical flavor and unique properties.

2. Method and Material

2.1. Pepper Samples

Black pepper samples were sourced from major cultivation and harvesting locations in Vietnam such as Quang Tri, Gia Lai, and Dak Nong provinces. The collected samples were subjected to drying processes to ensure moisture content below 15%, in accordance with Vietnamese Standard TCVN 7036:2008. Following collection, each sample was meticulously labeled and stored in airtight zip-lock bags. These bags were then placed within a cabinet to prevent direct sunlight exposure and maintained at ambient temperature.

In the process of reduction of descriptors for black pepper odor, the panel evaluated three representative black pepper samples from Quang Tri, Dak Nong, Dak Lak and Gia Lai provinces. These peppers were selected based on the results of a sorting test applied to 13 black pepper samples, which covered all aspects of black pepper odor and were representative of the sample set (Table 1). Additionally, to identify the most suitable sample preparation method for the next training and sample evaluation experiments, each representative black pepper code was prepared in both ground and extract forms. The selection of the most suitable sample preparation method is crucial for ensuring the reliability and consistency of sensory evaluation data, ultimately contributing to the refinement of descriptive terms for black pepper odor.

For ground pepper sample preparation, 2g of each representative black pepper was placed in a 100 ml dark glass flasks with a lid. The flasks were sealed and left for 30 minutes before evaluation to allow the odor to fully develop [7]. In the preparation of pepper extract samples, 1g of ground pepper powder from each representative source was extracted in a water solution at a ratio of 1g/100 ml for 30 minutes. The extract was then filtered using filter paper, and 30 ml of the extract was prepared in a 100ml dark glass jar for each sample. The flasks were sealed and left for 30 minutes before evaluation to ensure consistency in odor development [11].

Table 1: Information of pepper sanples

No	Sample	Code	Region	Type of pepper	Harvest time	Testing
1	**02649_26**	254	Quang Tri	Vinh Linh	5/2022	Sorting test, Reduction of descriptors
2	**00389_03**	769	Dak Nong	Vinh Linh	02/2022	Sorting test, Reduction of descriptors
3	**02422_04**	913	Gia Lai	Vinh Linh	04/2021	Sorting test, Reduction of descriptors
4	00527_06	491	Dak Lak	Vinh Linh	03 - 05/2022	Sorting test
5	00426_07	352	Dak Lak	Vinh Linh	03 - 05/2022	Sorting test
6	00537_13	378	Dak Lak	Vinh Linh	03 - 05/2022	Sorting test
7	00402_07	131	Dak Nong	Vinh Linh	03/2022	Sorting test
8	00389_02	495	Dak Nong	Vinh Linh	02/2022	Sorting test
9	02485_05	586	Gia Lai	Vinh Linh	04/2021	Sorting test
10	02455_03	622	Gia Lai	Vinh Linh	03/2021	Sorting test
11	08299_16	847	Quang Tri	Vinh Linh	11/2021	Sorting test
12	02649_40	455	Quang Tri	Vinh Linh	5/2022	Sorting test
13	08198_05	774	Quang Tri	Cua	6/2021	Sorting test

2.2. The Sensory Panel

The sensory evaluation panel for black pepper odor assessment comprised ten members, including three males and seven females. These individuals were carefully selected from Hanoi University of Science and Technology and were between the ages of 20 and 23. The panel selection process involved a three-step procedure: registration, screening, and interview. This rigorous selection process was guided by the principles outlined in ISO 8586:2014 and TCVN 12389:2018, ensuring the panel's adherence to international standards for sensory evaluation.

2.3. Processing of Vocabulary Development

In three sessions dedicated to term reduction, 10 members of the evaluation panel assessed 6 pepper samples in two preparation states: ground pepper and pepper extract. The panel used a 5-point scale to evaluate the intensity of the descriptions of the pepper samples' odors, where 0 indicated no perception, 1 was very weak, and 5 was very strong perception. For each evaluation session, the 6 samples were divided into two assessment rounds: the first one evaluated the pepper extracts, and the second one evaluated the ground pepper samples, with a 30-minute break between rounds.

During each term reduction session, after evaluating the samples, the panel was presented with the evaluation results, followed by a discussion of the results and the descriptive list. This descriptive list was refined in each session based on the panel's evaluations and consensus. After finalizing the list of descriptive terms, the committee proceeded to define and identify references for the descriptions in the subsequent two sessions. A range of references was introduced, and the committee members selected the most appropriate references for each description. During this process, any unsuitable descriptions were further eliminated.

2.4. Data Analysis Methods

The multivariate analysis methods used included Principal Component Analysis (PCA) [12], DISTATIS analysis [13], and Multiple Factor Analysis (MFA) [14]. All these methods were performed using the open-source software R. The DISTATIS method was used to obtain results for the free sorting test. The PCA method was applied to the evaluation results of samples during the term reduction sessions, providing insights into the correlations between the products and the observed variables. The MFA was used to combine the results of the three reduction sessions, offering a comprehensive overview of the panel's performance across the training sessions.

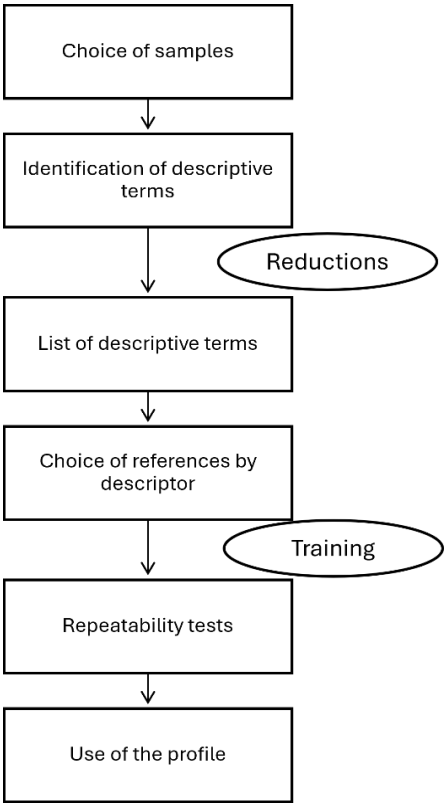

Fig. 1. Process of the identification and selection of descriptors for establishing a sensory profile (according to ISO 11035:1994)

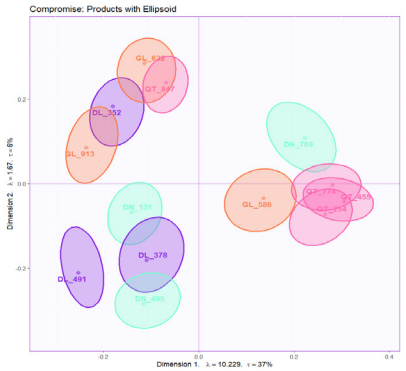

Fig. 2. DISTATIS analysis

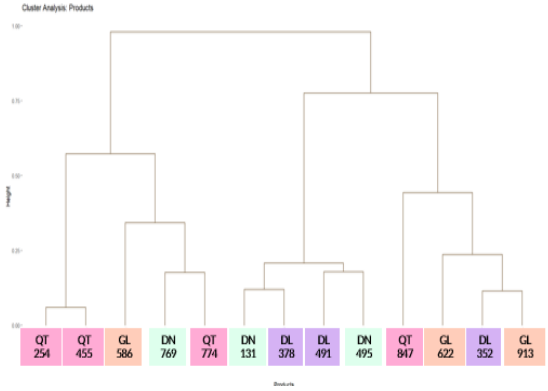

Fig. 3. Hierarchical cluster result

To further refine and validate the selected sensory descriptors, the study employed statistical methods, namely geometric mean calculation and frequency analysis, providing valuable insights into the relative importance, usage patterns, and potential redundancy of the terms [15]. The geometric mean of each descriptive term was calculated, serving as a crucial indicator of its relative weight in the overall panel evaluation. Terms with a geometric mean below 0.1 were considered for potential removal from the descriptor list by the sensory panel, prompting discussions on their relevance and appropriateness. This rigorous assessment ensured that only the most meaningful and representative terms were retained in the final descriptor list. Here is an explanation of the formula for calculating the geometric mean of each term:

$$M = \sqrt{F \times I} \quad (1)$$

Where:

M is Geometric mean of the term

F is Frequency of occurrence of the term

I is Relative score of the term

3. Results

3.1. Development of Initial Descriptors List

Based on the results of DISTATIS and cluster analysis for sorting data, the 13 pepper samples were divided into three main groups as illustrated in Fig. 2 and Fig. 3. Group 1 consisted of four samples, including two from Gia Lai (622, 913), one from Dak Lak (352), and one from Quang Tri (847). Group 2 comprised five samples, three from Quang Tri (774, 455, 254), one from Gia Lai (586), and one from Dak Nong (769). Group 3 included four samples, two from Dak Lak (491, 378), and two from Dak Nong (131, 495). This variation could be attributed to differences in storage conditions, harvesting time, or cultivation practices among the households, leading to distinct sensory profiles. Furthermore, based on the grouping results, three pepper samples were selected from each group as representative samples for evaluation during the sample reduction stage (254 from Quang Tri, 769 from Dak Nong, 913 from Gia Lai). These representative pepper samples, chosen based on the sorting method, are expected to cover all aspects of black pepper odor characteristics. The description list should encompass all the characteristics of the samples to prevent panel members from being disappointed when they cannot

rate a specific characteristic or must rate it under another characteristic [16].

In addition to the sorting task, the untrained assessors were also responsible for providing descriptions of the characteristics of each group. For this task, they were provided with a list of suggested descriptors compiled by the authors from relevant literature [5, 7, 8, 17-19]. The assessors were free to use this list or their own language to describe the groups. This initial list of descriptive terms was constructed by combining the descriptors used by the panelists. These terms used by the panel could be referenced from reference materials or from the panel's own descriptions. As a result, the initial list of descriptors for describing the odor characteristics of black pepper included 33 terms expressed in both Vietnamese and English (Table 2). This list of terms was selected as the initial set for use by the panel during the initial reduction of terms phase.

3.2. Reduction of Descriptors

In the first session, the panel evaluated the pepper samples using the 33 initial descriptive terms (Table 2). The geometric mean (*M*) of the terms "fermented," "almond", "coconut", and "rotten" was found to be less than 0.1, indicating that the panelists less frequently used these four terms to describe the odor of pepper (Fig. 4). Therefore, these terms were to be discussed by the panel to assess their relevance.

The results of the principal component analysis (PCA) for session 1 are shown in Fig. 5. The total variance explained by the first principal plane was 65.59%. PC1 accounted for 44.26% of the total variance and was primarily associated with two sample states: ground and extract.

Table 2: List of terms

No.	Vietnamese term	English meaning
1	Thông	Pine
2	Thuốc bắc	Chinese herb like
3	Bạc hà	Minty
4	Tươi mới	Fresh
5	Họ cam chanh	Citrus
6	Tiêu	Pepper
7	Vỏ cây	Bark
8	Nhựa cây	Resinous
9	Gỗ	Woody
10	Cỏ	Grassy
11	Thuốc	Medicine like
12	Gia vị	Spice
13	Thảo mộc	Herb
14	Xanh	Green
15	Đất	Earthy
16	Đắng	Bitter
17	Thì là	Dill
18	Sắc nét	Sharp
19	Nhựa thơm	Balsamic
20	Chua	Sour
21	Ô mai	Salted dry apricot
22	Lên men	Fermented
23	Thuốc kháng sinh	Antibiotic like
24	Dầu khoáng	Petroleum like
25	Long não	Camphoraceous
26	Bơ	Butterry
27	Ngọt	Sweet
28	Hương hoa	Floral
29	Béo	Fatty
30	Ôi	Rotten
31	Dừa	Coconut like
32	Hạnh nhân	Almond like
33	Nhựa thông	Turpentine like

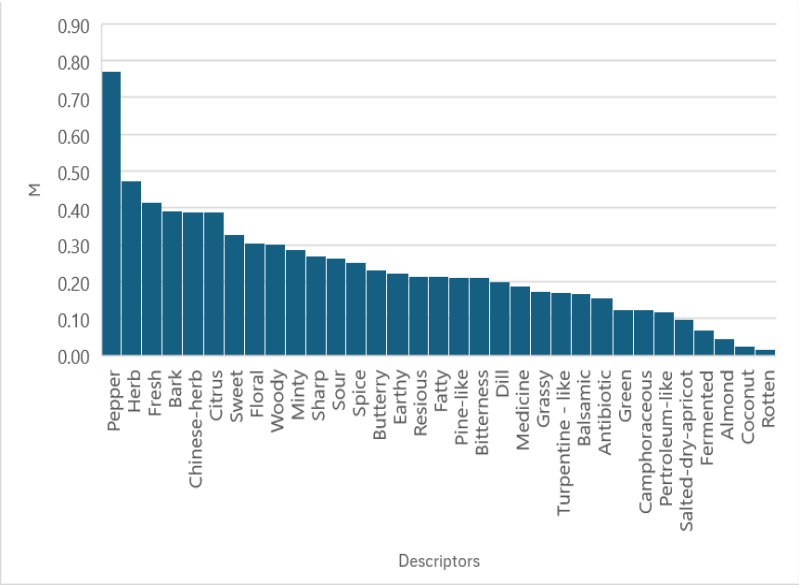

Fig. 4. The geometric mean of descriptors in session 1

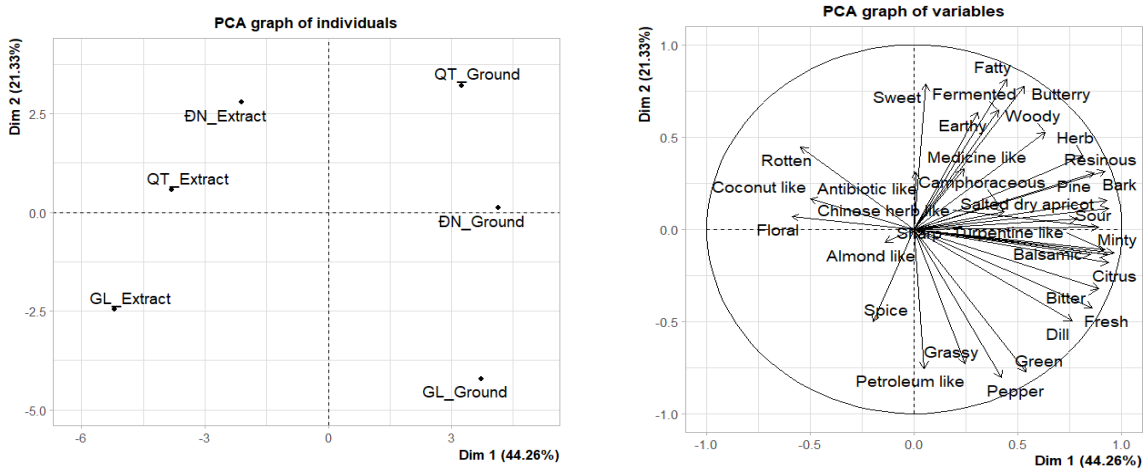

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Fig. 5. Principal component analysis of 33 terms from session 1

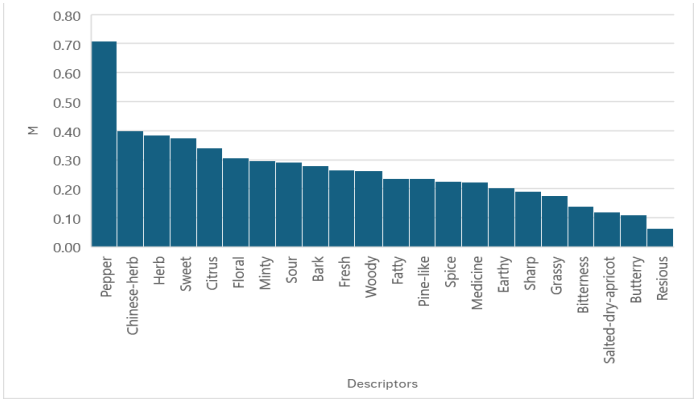

Fig. 6. The geometric mean of descriptors in session 2

Ground pepper samples were located on the positive side of the PC1 axis, while extract samples were located on the negative side. This suggests that ground pepper samples were characterized by a majority of the descriptors in the list, such as "salted dry apricot," "Chinese herb," "minty," "sharp," "pine," "balsamic," and so on; extract samples had a weaker odor than ground samples as they were described by fewer odors. PC2 explained 21.33% of the total variance and played a significant role in indicating the characteristics of pepper samples from different growing regions. Ground pepper from Quang Tri was characterized by the properties "buttery", "fatty", "sweet," "fermented", "earthy", etc. Ground pepper from Gia Lai was characterized by the properties "green", "grassy", and "pepper". On the other hand, ground pepper Dak Nong was characterized by the properties "Chinese herb", "pine-like," "salted dry apricot," and "sharp." However, it was observed that some terms were correlated and overlapped, and the panel needed to discuss clarifying, merging, or removing them from the list of descriptive terms.

Following the presentation of the results of the pepper sample evaluation from session 1, the panel discussed the results and the descriptors. The panel agreed to consolidate "pine-like" and "turpentine-like" into the “pine” term and "grassy" and "green" into the “grassy” term as the panel assessed these descriptors similarly. Additionally, the terms "rotten", "coconut", "fermented", "dill", "antibiotic", "petroleum-like", "camphoraceous", and "almond" were unanimously removed as they were not representative of pepper odor and were used by a small number of panelists. The descriptor "balsamic" was temporarily removed due to the panel members' lack of understanding of the term. The descriptions used must be agreed upon by a majority of panel members to ensure consistency in the council's scoring method in support of the common goal of ensuring accurate communication among members [16]. If only one or two members rate a characteristic, it does not provide the necessary data to make a decision. Therefore, it is necessary to explain to members so that their suggestions are valued and

that not including them is not a denial of their contribution to the panel.

In summary, after the first session, through the evaluation results and discussions, 9 descriptors were removed, and 4 descriptors were consolidated into 2 descriptors. The list of descriptive terms was reduced from 33 to 22 after the first session.

In session 2, the reduced list of 22 descriptors was used and evaluated similarly to session 1. Geometric mean analysis and PCA were applied to assess the results of the panel's pepper sample evaluation. The descriptor "resinous" had an *M* value of less than 0.1, indicating that the panel tended to use this term less frequently for evaluation (Fig. 1).

The results of PCA for session 2 are shown in Fig. 7. The information explained is similar to that in Session 1, with PC1 primarily explaining information related to sample state and PC2 explaining information related to geographic origin. In Session 2, ground pepper samples form Gia Lai and Dak Nong were evaluated similarly, characterized by the properties "woody", "bitter", "sour", and "fresh"; ground sample from Quang Tri was located alone in the fourth quadrant, indicating a more distinctive odor compared to the other two samples, characterized by the descriptors "floral", "herbal", and "buttery". The results regarding the odor characteristics of the pepper samples were slightly different between session 1 and session 2. This could be attributed to the inconsistent performance of the panel and the changes in the descriptor list between the first two sessions. This is understandable as the panel is still in the early stages of training.

Similar to the first session, after being presented with the results, the panel focused on discussing the results and the descriptor list. The terms "resinous," "bark," and "medicine" were found to be confusing and were used by only a few panelists to describe the samples. Therefore, these terms were unanimously removed from the descriptor list by the panel. Additionally, "sharp" and "fresh" were also agreed upon for removal due to a lack of clarity among most panelists and overlapping evaluations with other descriptors. Ensuring that panel members have a clear understanding of the descriptions is crucial for producing meaningful results and guaranteeing that members share a common understanding and avoid communication errors [20]. Additionally, the chosen terms must not overlap with other terms to prevent confusion among members and potential errors in evaluation results. In the second session, 5 descriptors were removed.

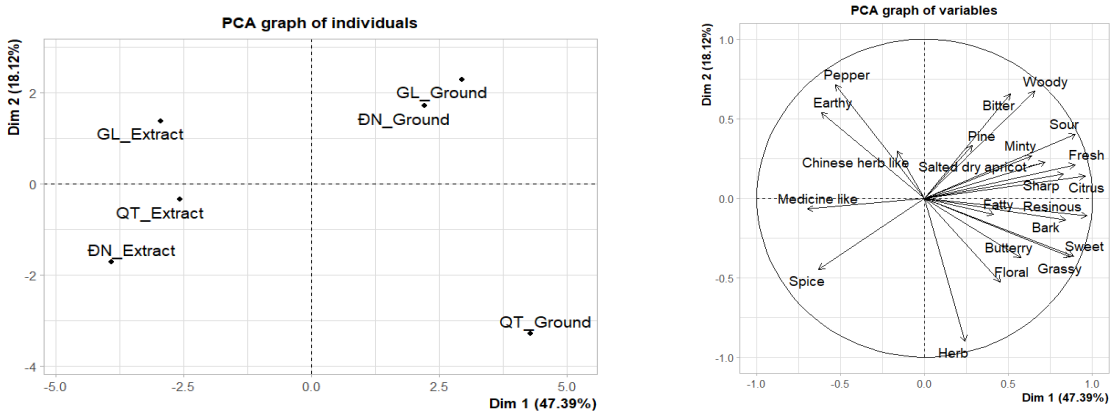

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Fig. 7. Principal component analysis of 22 terms from session 2

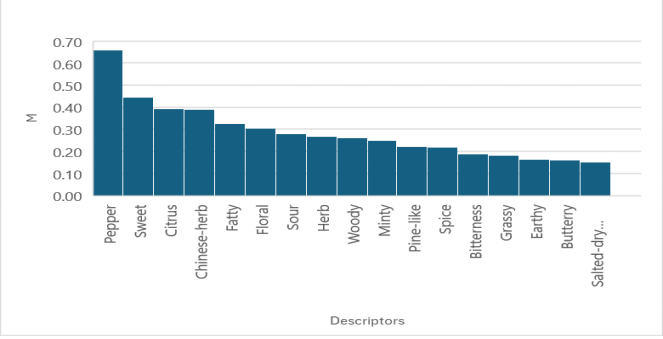

Fig. 8. The geometric mean of descriptors in session 3

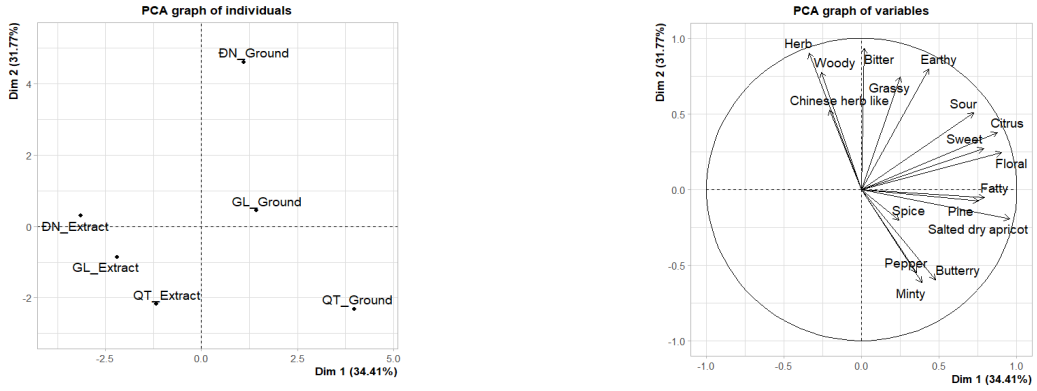

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Fig. 9. Principal component analysis of 17 terms from session 3

In session 3, the panel continued to evaluate the pepper samples using the 17-term list after the reduction in session 2. The results were again assessed using *M* and PCA analysis. The descriptive terms all had *M* values greater than 0.1 (Fig. 8), indicating that the descriptors in the list were being used by the panel to describe the pepper samples. The total variance explained by the first two principal components was 66.18% (Fig. 9). The results of the PCA showed positive signs in the panel's evaluation of the reduced term list after two sessions. This was reflected in the increased variance explained by PC2, which explains information related to the characteristics of each growing region. This result suggests that the panel's ability to use the descriptor list to distinguish characteristics based on origin increased after three evaluation sessions.

Through PCA analysis on all three sessions of the reduction process, it could be seen that the distribution of patterns on the first plane is similar. Dim 1 axis shown information related to the state of the standard sample or extraction, while dim 2 axis shown information related to the discrimination of the origin of the standard samples. The variance explained by dim 2 axis increases from session 1 to session 3, increasing from 21.33% to 31.77%. This result suggests that changing the terminology by removing or grouping is effective in discriminating the origin of the standard samples.

In addition, during the discussion in session 3, the descriptors "pepper," "herbal," and "spice" were unanimously agreed upon by the panel to be too general and not capable of distinguishing between the pepper samples; the descriptor "woody" was evaluated as having weak intensity and being similar across the samples; the descriptors "bitter," "sweet," and "sour" were deemed inappropriate as odor descriptors and overlapped with the descriptors "floral" and "citrus." The terms should reflect the attributes that distinguish between evaluation samples, highlighting the dissimilarities between the samples [16]. This aligns with the research objective of identifying the distinctions between target samples from diverse origins. At the end of Session 3, 7 more descriptive terms were reduced, resulting in a final consensus list of 9 descriptive terms that met the established criteria.

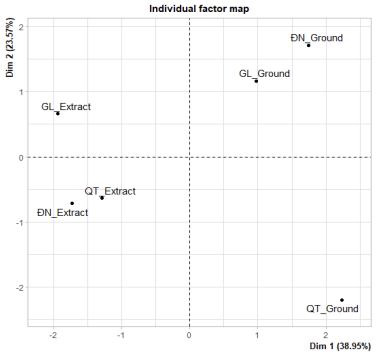

Fig. 10. Representation of pepper samples on the first plane of the MFA of session 1,2,3

To gain a comprehensive overview of the observations and relationships between groups of variables in the results of the three term reduction sessions, Multivariate Factor Analysis (MFA) was performed on the data collected from all three evaluation sessions. The MFA results showed that the first axis was associated with information about the sample state (ground or extraction pepper), while the second axis was associated with geographical origin (Fig. 10). Fig. 10 shows that ground Quang Tri pepper has unique characteristics compared to the other two regions, as it is located alone in the fourth quadrant on the first plane, while ground Gia Lai and Dak Nong pepper show similarities as they are located close together on the plane.

Table 3: RV of sessions and MFA

	Session 1	Session 2	Session 3	MFA
Session 1	1.000	0.875	0.836	0.938
Session 2	0.875	1.000	0.903	0.968
Session 3	0.836	0.903	1.000	0.962
MFA	0.938	0.968	0.962	1.000

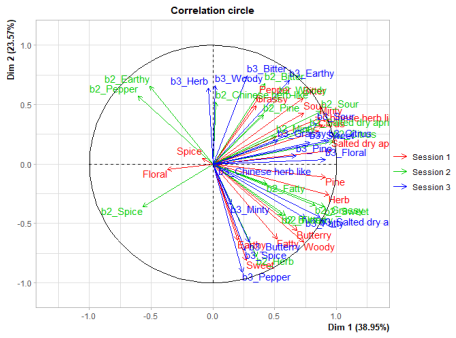

Fig. 11. Representation of descriptors on the first plane of the MFA of session 1,2,3

Fig. 11 showed there were some differences in the results across the three reduction sessions. This was evident in the evaluation of some odor descriptors, such as "woody," "spicy," "pepper," and "floral." These differences are understandable given that the panel is still in its early stages and has not yet undergone a thorough process of definition standardization, reference selection, and scale training. Therefore, during the development phase of descriptive terms, panel discussions play a crucial role in understanding the panel's interpretation of the terms and their evaluation methods, leading to the selection of the most appropriate term list. Furthermore, the term list obtained after the reduction process may not be the final list and will need to be adjusted and discussed throughout the subsequent training process to ensure that it aligns with the panel's development progress over time.

However, the MFA analysis results suggest that the panelists' evaluations were quite consistent across the three sessions, indicating the panel's good performance despite being in the early stages of training. This is reflected in the high RV coefficients between sessions and with MFA. The high RV coefficients between sessions and MFA suggest that the results of evaluating the properties on the descriptor are similar (Table 3). This consistency is also reflected in figures of representation of the partial axes (principal components of the separate PCAs) and representation of groups of variables on the first plane of the MFA. The first two dimensions of the MFA are closely linked to the first two dimensions of each of the separate PCAs (Fig. 12). Additionally, in Fig. 13, the acute angles formed between dim1, dim2 of the 3 sessions indicate that the sessions were similar.

Furthermore, the analysis results also indicated that ground pepper samples exhibited a wider range of odors compared to extracted samples. Therefore, ground pepper will be prioritized as the standard sample preparation method for the next training phase and evaluation stage. The reason for including extracted samples in the evaluation alongside ground samples was to determine the most suitable sample preparation method for the subsequent stages of panel training. While extracted samples showed fewer odors than ground pepper, this preparation method offers the advantage of easily creating pepper samples with varying odor intensities for subsequent scale training. Hence, combining these two sample preparation methods is crucial for optimizing the effectiveness of the next training phase.

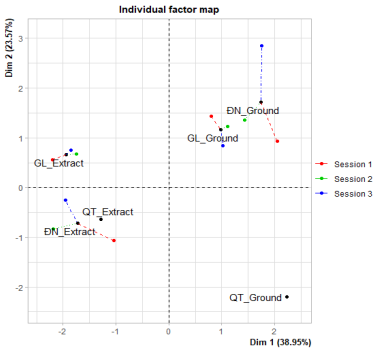

Fig. 12. Representation of the mean and partial individuals on the first plane of the MFA of session 1, 2, 3

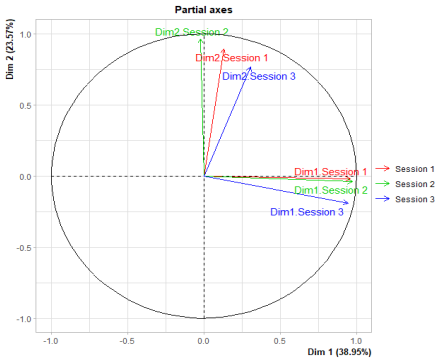

Fig. 13. Representation of the partial axes on the first plane of the MFA of session 1, 2, 3

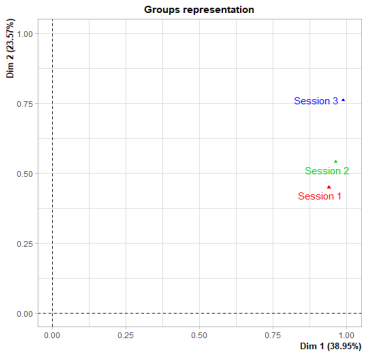

Fig. 14. Representation of groups of variables of session 1, 2, 3

3.3. Defining and Referencing - The Final Descriptors List

Following the completion of the three term reduction sessions, the panel continued to work for two more sessions with the aim of clarifying the panelists' understanding and establishing a consensus on the panel's evaluation approach. In Session 4, the panel was introduced to different references for the 9 descriptors on the reduced list and rated the level of appropriateness on a scale. The panel then discussed and selected the reference samples considered most appropriate for the descriptors. The references used here included food-based and chemical-based references to help the panel visualize and understand the descriptor terms more clearly. In Session 5, the panel continued to discuss the terms and develop definitions for each descriptor. This session aimed to help the panel achieve a unified understanding and evaluation approach. During this session, the panel further discussed and agreed on changes to the term list, adding, removing, or modifying existing terms. The results of the two reference discussion and evaluation sessions are detailed in Table 4, which includes the descriptor terms, corresponding definitions, and references for each term. Following these two sessions, the term list was further revised. The two descriptors "lime" and "pomelo flower" were approved by the panel for inclusion in the term list after being introduced to the references of green lime peel and linalool standard. Additionally, the descriptor "earthy" was unanimously agreed to be changed to "stale" to better align with the panel's evaluation approach.

After three term reduction sessions, one reference introduction session, and one definition building session, the final descriptor list for ground pepper odor comprised 11 terms that received the consensus and satisfaction from the panel members.

Table 4: List of pepper odor descriptors, definitions, and references

No	Descriptor in English	Definition in English	Descriptor in Vietnamese	Reference
1	Fatty	A rich, creamy odor reminiscent of butter	Béo	Melt westgold unsalted butter
2	Lime	A sharp, acidic odor reminiscent of lime	Chanh xanh	Fresh lime peel
3	Salted.dry apricot	A fermented odor reminiscent of fermented apricots	Ô mai	Tien thinh canned soft apricots
4	Grassy	A green odor reminiscent of freshly cut grass	Cỏ	Freshly cut gras
5	Citrus	A fresh delicate odor with a balance of sourness and sweetness	Cam chanh	Australian orange peel
6	Minty	A refreshing, menthol odor reminiscent of mint	Bạc hà	Ricotta mint candy
7	Chinese.herbs	A odor with a blend of bitterness, earthiness, sweetness, and warmth, reminiscent of certain herbs or spices	Thuốc bắc	Cam xuyen huong herbal medicine
8	Pine - like	A resinous, woody odor reminiscent of pine trees	Thông	Pinene (sigma)
9	Pomelo flower	A floral odor reminiscent of pomelo flowers	Hoa bưởi	Linalool (sigma)
10	Stale	A damp, earthy odor reminiscent of petrichor, soil, or mushrooms	Cũ	Wet rotten bark
11	Floral	A delicate, sweet odor reminiscent of pollen	Hương hoa	Pollen

4. Conclusion

This study successfully developed a list of 11 descriptors to characterize the odor of Vietnamese black pepper from different growing regions. The methodology involved a rigorous process of sensory evaluation by a selected panel, employing various data analysis techniques to refine the initial list of descriptors.

This comprehensive descriptor list serves as a valuable tool for evaluating the quality and unique odor profiles of Vietnamese black pepper, differentiating pepper from various growing regions within the country. It empowers stakeholders in the Vietnamese pepper industry, including producers, processors, exporters, and quality control personnel, to effectively assess and describe the sensory characteristics of their products. Additionally, this research contributes to establishing a vocabulary for Vietnamese black pepper, facilitating communication and understanding throughout the pepper production and trade chain.

Future research could explore expanding the panel size and expertise to enhance the generalizability and robustness of the findings. Further investigation into the correlation between these odor descriptors and the chemical composition of pepper samples from different regions could provide valuable insights into the factors influencing odor profiles.

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