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The Odor Value Approach to Aroma Contribution Analysis and Aroma Mapping: A Systematic Review

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Abstract

Aroma is a complex matrix consisting hundreds of volatile compounds, so there are challenges in understanding aroma characteristics and their mapping. There is an approach called odor value that connects chemical information with sensory perception and provides a visual tool for aroma mapping. However, literature studies of Odor Value are rare. This study aims to review the principle of odor value in aroma contribution analysis and how it can be integrated with the Perfumery Ternary Diagram for aroma mapping. The article selection method used the PRISMA guideline with the keywords odor value and aroma analysis published from 2005-2025 in the ScienceDirect database and obtained 10 articles that met the criteria. This method can provide initial understanding and map the scope of the available literature. From the review results, it is known that odor value is influenced by the concentration of compounds in the headspace, aroma threshold values, activity coefficients, and molecular interactions. In addition, the integration of odor value into the Perfume Ternary Diagram plays a direct role in determining the aroma mapping pattern so that it can provide information about aroma dominance, component diffusion in the matrix, and the influence of solvents in the matrix.

Keywords: Odor Value, Perfumery Ternary Diagram, Aroma Analysis, Aroma Contribution, Aroma Mapping

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Aroma adalah matriks kompleks yang terdiri dari ratusan senyawa volatil, sehingga terdapat tantangan dalam memahami karakteristik aroma dan pemetaannya. Terdapat pendekatan yang disebut *odor value* yang menghubungkan informasi kimia dengan persepsi sensorik dan menyediakan alat visual untuk pemetaan aroma. Namun, studi literatur tentang *odor value* masih jarang dilakukan. Reviu ini bertujuan untuk meninjau prinsip Nilai Aroma dalam analisis kontribusi aroma dan bagaimana hal itu dapat diintegrasikan dengan *Perfumery Ternary Diagram* untuk pemetaan aroma. Metode pemilihan artikel menggunakan panduan *PRISMA* dengan kata kunci *odor value* dan *aroma analysis* yang diterbitkan dari tahun 2005-2025 dalam basis data *ScienceDirect* dan diperoleh 10 artikel yang memenuhi kriteria. Metode ini dapat memberikan pemahaman awal dan memetakan ruang lingkup literatur yang tersedia. Dari hasil tinjauan, diketahui bahwa *odor value* dipengaruhi oleh konsentrasi senyawa dalam fasa gas di atas larutan *(headspace),* nilai ambang batas aroma, koefisien aktivitas, dan interaksi molekuler. Selain itu, integrasi *odor value* ke dalam *Perfumery Ternary Diagram* berperan langsung dalam menentukan pola pemetaan aroma sehingga dapat memberikan informasi tentang dominasi aroma, difusi komponen dalam matriks, dan pengaruh pelarut dalam matriks.

Kata Kunci: Odor Value, Perfumery Ternary Diagram, Aroma Analysis, Aroma Contribution, Aroma Mapping

INTRODUCTION

Aroma (odor) is an outcome of volatile compounds which released into the air and interact with the human olfactory receptor system [1,2]. One of the application aroma concepts is fragrance and flavor products. Data from grand review research [3] shows that the global fragrance market was estimated to reach US$32,265 million in 2024 and is projected to reach US$52,388 million by 2033. This increase indict industry to make innovation both in aroma analysis, aroma mapping, and aroma formulation. However, aroma is a complex matrix that can consist of hundreds of volatile compounds. It is the reason why understanding aroma characteristics and mapping them is challenging. Aroma characteristics in multicomponent systems are often nonlinear, so the contribution of a volatile compound is not proportional to its concentration. Key aroma compounds are often found at very low concentrations but contribute significantly to the overall aroma, while other compounds are found at high concentrations but do not contribute significantly. The final aroma characteristics are not the sum of each compound's aroma. It is the result of interactions between compounds which involve synergistic, additive and antagonistic effects. Furthermore, aroma descriptions are prone to have overlapping perceptual. This is because a single compound can have more than one aroma description, and several compounds can produce similar sensations, making it is difficult to map the overall aroma [4,5].

Various scientific methods have been used in aroma analysis. One of them is Gas Chromatography-Olfactometry (GC-O) which uses the human nose as a sensory detector for chromatographic eluents. In the GC-MS-O system, the olfactory port (sniff) operates in conjunction with a mass spectrometer (MS) detector. This facilitates the identification of aroma compounds and their detection by the human nose through the sniffer [6]. In addition, considering that each panelist has different olfactory sensitivity and olfactory threshold, also aroma perception is greatly influenced by psychological factors, nasal fatigue, experience, and memory associations. Repeated confirmation is required for the same panelists (intra-individual repeatability) and different panelists (inter-individual reproducibility) [7]. Therefore, it can be said that GC-O-MS is subjective, repetitive, and not quantitative.

Another method that has been used is Aroma Extract Dilution Analysis (AEDA). This method creates a sample by diluting aroma extracts at a specific ratio, followed by olfactory examination by at least two trained panelists. This means that Dilution Factor indicates the potential for a compound to be detected under isolated conditions (on a GC column), but not explain how the compound interacts and contributes to the aroma matrix. This method also cannot stand alone because it does not provide data on the concentration of volatile compounds [8].

The limitations of both methods show that is necessary to develop an integrated approach which connect chemical aspect with sensory perception in a quantitative, objective, and standardized representation. Furthermore, an approach should capable of provide a visualization for scientific analysis, comparison, and predicting aroma characteristics. Method that can address this limitation is Odor Value (OV). It assesses the contribution of each compound based on the ratio between its actual concentration and its aroma perception threshold. Odor Value highlights compounds that being present at low concentrations but have significant aromatic impact [9].

Even though there are several experimental research about Odor Value in quantifying aroma contributions, literature studies discussing the principles, relationships, and applications of aroma analysis using Odor Value and its correlation in aroma mapping on the Perfumery Ternary Diagram (PTD) are still limited. The existing literature consists mostly of separate research articles that focus on specific matrix. The existing literature also does not provide a comprehensive understanding of the advantages of integrating Odor Value with the Perfumery Ternary Diagram. Integration of both provide an overview of how changes in the proportion of a compound affect the overall aroma character, aroma dominance, transition zones, and potential interactions between compounds in forming a specific aroma profile. This shows the urgency to make preliminary assessments to map the scope of available literature and provide a broad evaluation of existing evidence. It is necessary to systematically interpretate a few articles that provide data quantification of aroma contribution through Odor Value and visual representation of aroma through Perfumery Ternary Diagram in an integrated manner, so that both can be understood in one complete analytical framework. Based on this description, this paper aims to review the Odor Value approach in analyzing aroma contribution, as well as review the relationship between the Odor Value approach and aroma mapping in the Perfumery Ternary Diagram system.

METHODS

Literature Search

This study employed a systematic literature review following the PRISMA guidelines. It was chosen to bridge the gap and provide initial understanding and map the scope of the available literature [10]. The literature search was conducted through the ScienceDirect database. Keywords used included "Odor Value" and "Aroma Analysis." Initially, 273 articles were identified. The selected articles were then analyzed using narrative synthetic approach.

Inclusion and exclusion criteria

The initial screening process was conducted to ensure the relevance and minimize selection bias of the obtained literature [10]. The inclusion criteria used were research paper that have been published between 2005-2025. A 20-year period was selected to represent the contemporary issues of aroma (odor). The literature that passed this selection stage was 211 articles. In line with the Odor Value oriented approach, articles inside the subject of chemistry, and chemical engineering were included. The selection continued with exclusion criteria such as articles without full access (abstract-only). From this stage, 30 articles were obtained. Further selection was carried out through abstract skimming which included Odor Value and its interpretation. The final number of articles obtained was 10 articles. The results of the article selection are described in detail using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flowchart as follows (**Figure 1**).

Data collection and interpretation

Given the diverse types of articles, they were divided into two categories according to their primary focus [11]. First, study centered on aroma analysis. Second, study centered on aroma mapping. The data collection process was carried out by reviewing each selected article to obtain information on the type of matrix, active aroma compounds, odor value of active compounds, aroma contribution based on odor value, the system used in the perfumery ternary diagram (PTD), and aroma mapping based on PTD visualization. The data obtained were presented narratively. Interpretation was carried out by providing meaning to the odor value data of active compounds with their contribution to the overall aroma character of the matrix, factors that influence the odor value, potential interactions between compounds that influence aroma characteristics, the influence of the odor value on the dominant aroma mapping, and the influence of changes in the odor value on the overall aroma mapping visualization.

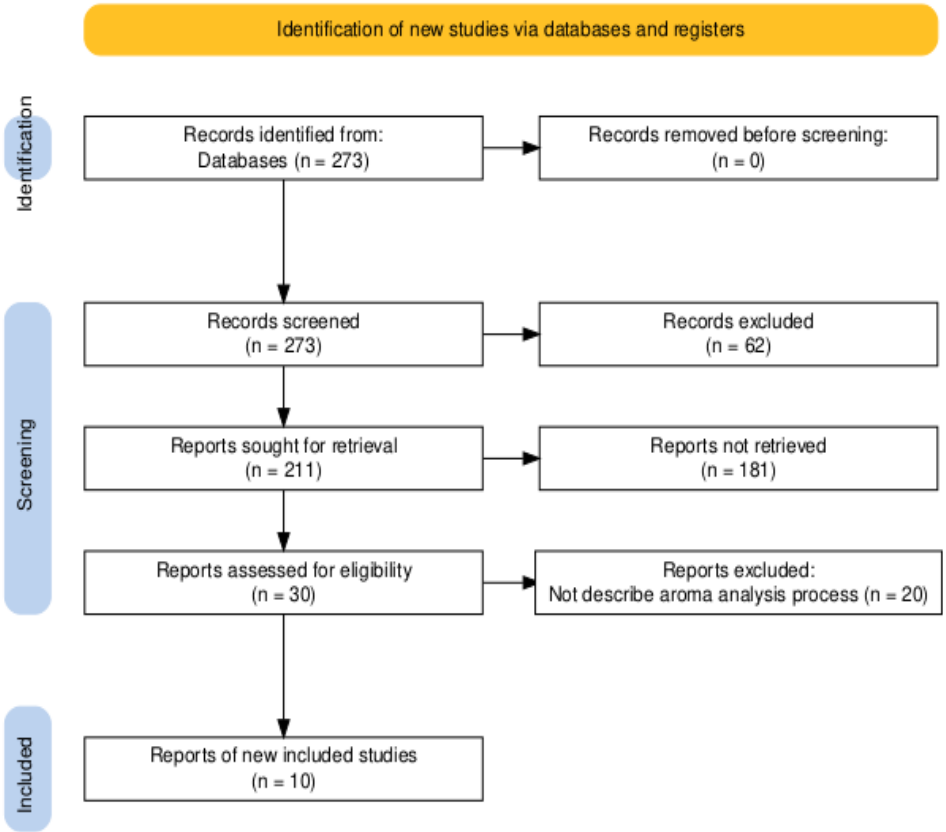

Figure 1. PRISMA Flowchart

Table 1. Odor Value and Aroma Contribution

Ref	Matrix	Aroma Dimention	Odor Active Compound	OV
[12]	Chinese Traditional Beer	Nutty Caramel-like Floral Sweaty	Phenyl-ethyl-ethanol, Ethyl-hexanoat, Octanoic acid, Maltol, Hexanoic acid, Furfural	797 467 234 30 19 1
[13]	Laoshan Green Tea	Fresh Floral and Typical green tea aroma	Dimethyl sulfide, 3-Methyl-buthanal, (z)-Jasmone, Furanerol, Indole	126 68 16 8 1
[14]	Huangjiu (Chinese Rice Wine)	Fruity Floral	2-Phenyl-ethyl-alcohol, 1-Octen-3-ol, 2-Nonanol, 2-Phenyl-ethyl-acetate, Isoamyl acetate,	>1
[15]	Gamma-amino butyric acid (GABA) Tea	Floral Fruity	β-damascenone, Linalool, (Z)-Jasmone, 1-Octen-3-ol, Decanal	100 < 100
[16]	Light Flavour Baijiu	Floral Fruity	β-damascenone, 4-Ethyl-guaiacol, Ethyl-octanoat, Phenyl-acetal-dehyde	26 4 2 2

RESULTS AND DISCUSSION

Aroma Analysis

Based on the search and selection of articles, the contribution of aroma data from various multicomponent system matrices was obtained, which is presented in **Table 1**. Aroma is the volatile fraction sensed in the olfactory bulb of the nose. A multicomponent aroma system refers to a mixture of aromas composed of many volatile compounds with varying concentrations and aroma thresholds. Also, human olfactory perception is not always linear with relative concentration. From **Table 1**, we can see that compound which contributes significantly to the overall aroma has odor value >1. **Table 1** also shows that matrices 1 to 5 tend to have a sweet aroma with a floral hint. This indicates that each type of compound has a unique contribution to overall aroma. Alcohol and its derivatives are known as compounds that contribute to floral aroma, meanwhile phenol is known to malty and nutty aroma. On the other side, esters are known to contribute to fruity aroma, and aldehydes contribute to sweet honey-like aroma. Meanwhile acids exhibit unpleasant sweaty, sour and putrid odor [16]. Alcohol tends to produce floral aroma because they are volatile organic compounds and have low odor threshold. Functional group -OH have capacity to act as a polar hydrogen-bond donor and acceptor, allowing the molecule to bind specifically to human olfactory receptors. It possesses enough intermolecular force to be soluble in the mucus layer of the nose. Also, higher alcohol with carbon more than 3, usually found in plants that specifically activate human olfactory receptors associated with pleasant, flowery scents. [17].

Each matrix has odor active compound with high odor value, but this cannot be interpreted as a dominant aroma. For example, phenyl ethanol has a very high OV value, namely 797. It contributes to floral aroma, but in fact, this matrix has Nutty caramel-like dominance which contributed by maltol. On the other hand, Chinese rice wine matrix has ethyl ester with significant low odor value, but still contribute to aroma matrix. It is because in non-ideal mixture system, aroma density is influenced by activity coefficient due to the present of other compounds. Specifically, odor value can determine whether the molecular interaction is synergistic, additive, or masking [18]. This interaction is known in one of the processes of odor value calculation. First, we need to analyze existing functional groups, then thermodynamic modeling was

carried out using the Universal Quasichemical Functional Group Activity Coefficients (UNIFAC) approach. UNIFAC will break down compounds into functional groups [19]. Take the GABA tea matrix as an example. Linalool with a chemical structure as shown in **Figure 2**. will be broken down into -CH_3, -CH_2, -C, CH_2=CH, CH=C, -OH. Next, 1-Octen-3-ol with a chemical structure in **Figure 3**. Will be broken down into -CH3, -CH2, -CH, CH_2=CH, -OH. Next, 1-Octen-3-ol with a chemical structure in **Figure 3**. Will be broken down into -CH_3, -CH_2, -CH, CH_2=CH, -OH.

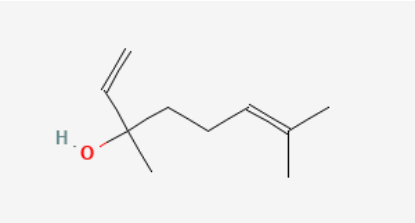

Figure 2. Structure of Linalool

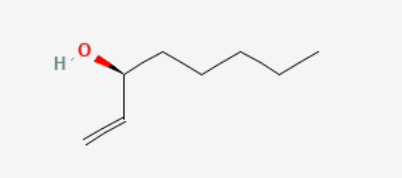

Figure 3. Structure of 1-Octen-3-ol

The interactions between these groups are calculated using the main interaction parameter, a_{mn}. A negative a_{mn} value indicates a strong affinity between the groups, thus providing a synergistic or additive effect. Vice versa [19]. For example, the interaction between -CH3 (from linalool) and -OH (from 1-Octen-3-ol) has an a_{mn} value of 986.5 (can be seen in the UNIFAC table). Therefore, the interaction is antagonistic. This is due to the inductive force between the polar -OH group and the nonpolar -CH3 group.

This confirms that OV functions well as aroma analysis method, because it considers matrix effects and volatile interactions in multicomponent systems.

Aroma mapping

We already know that Odor Value is a great method for aroma analysis in multicomponent system. Based on the article search conducted, Perfumery Ternary Diagram (PTD) aroma mapping data was obtained by integrating the Odor Value values presented in **Table 2**.

Odor value can be integrated into Perfumery Ternary Diagram by using tern plot and custom scripts on Phyton. The Perfumery Ternary Diagram (PTD) has three angles that distinguish regions between aroma components. The mapping by the PTD shows different regions for each compound. These differences in region size indicate the presence of the compound's aroma in the overall aroma matrix character. Aroma mapping is actually determined by how volatile compounds are "present" in the headspace and how their aroma contribution is calculated via odor value. In some cases, a solvent, usually ethanol (S), is introduced into the mixture, so the mole fraction of the solvent or xS is assumed to remain constant. Certain conditions can result in a solvent having the highest OV value, meaning the mapping shows the solvent's aroma dominating the fragrance matrix. This occurs when the solvent is present in significant amounts. This detailed categorization allows for precise fragrance aroma mapping [22].

The first matrix illustrates domination of Limonene in aroma matrix as shown in **Figure 4**. This predict that limonene will contribute >70 % to the overall odor. It happens because limonene has the highest odor value. The PTD shows that the highest response region is concentrated near component A, indicating that increasing the concentration of limonene in the headspace significantly increases the predicted aroma intensity. This occurs because limonene is a highly volatile monoterpene compound. The higher the volatility of a compound, the easier it is for the compound to enter the air. Thus, the concentration of compounds in the headspace becomes greater, so that the odor value increases. This is what causes the greater the concentration of compounds, the wider the aroma mapping.

Another matrix containing geraniol, Hebanolide, Iso-e-super [20] map domination of geraniol as shown in **Figure 5**. The PTD on the left maps three different aromas in solvent-free conditions, while the diagram on the right maps three different aromas when dissolved using mineral oil. The left diagram maps the aroma into 2 parts and does not show the hebanolide region, where the geraniol region is wider. This is in accordance with the calculation data where the geraniol OV always occupies the highest position in any concentration ratio, while the hebanolide OV always occupies the lowest position. This means that some compounds suppress hebanolide, preventing its aroma from significantly contributing to the aroma character of the matrix. This very low aroma intensity is consistent with predictions, given that hebanolide is a fixative compound, that is compound whose aroma tends to be invisible but plays a role in maintaining the perfume's scent. This phenomenon is closely related to vapor–liquid equilibrium, in which volatile molecules continuously partition between the liquid perfume

matrix and the surrounding gas phase until equilibrium is achieved. Compounds with higher vapor pressure evaporate more readily from the liquid phase into the gas phase, resulting in higher concentrations in the headspace and stronger odor perception. Geraniol, as an oxygenated monoterpene alcohol, exhibits moderate vapor pressure and relatively high odor activity, enabling sufficient volatilization into the gas phase to dominate sensory perception despite intermolecular competition within the liquid mixture. In contrast, hebanolide behaves differently because of its macrocyclic musk structure, larger molecular weight, and significantly lower vapor pressure. Thermodynamically, compounds with low vapor pressure possess lower escaping tendency from the liquid phase, meaning that fewer molecules transition into the gas phase at equilibrium conditions. Consequently, hebanolide remains predominantly retained within the liquid matrix and contributes minimally to the vapor composition detected by olfactory receptors. This behavior explains why the PTD does not show a distinct hebanolide dominance region. The system therefore reflects not only concentration differences but also the relative tendency of each molecule to distribute between liquid and vapor phases according to Raoult's law and non-ideal activity behavior.

Table 2. Odor Value (OV) and Perfumery Ternary Diagram (PTD) Mapping.

Ref	Matrix	Results
[1]	Limonene, Geraniol, Vanilin	Limonene who has the highest Odor Value dominates the diagram.
[20]	Geraniol, Hebanolide, Iso-E-Super,	Geraniol and Iso-e-super dominate the diagram, with geraniol having a larger area. Aroma map shifted when components are dissolved in mineral oil, aroma mapping shows that Iso-e-super tends to be more retained in the solution and can only be perceived strongly at low geraniol concentrations.
[21]	Alpha-pinene, Linalool, Vanilin	Aroma mapping showed that at 30% ethanol, all compounds were present and represented the aroma, and as the ethanol concentration increased, linalool and vanillin became less represented.
[22]	Limonene, Geraniol, Vanilin	Limonene dominates the diagram. Aroma map shifted when ethanol added. As more ethanol was added, geraniol and vanillin became less represented.

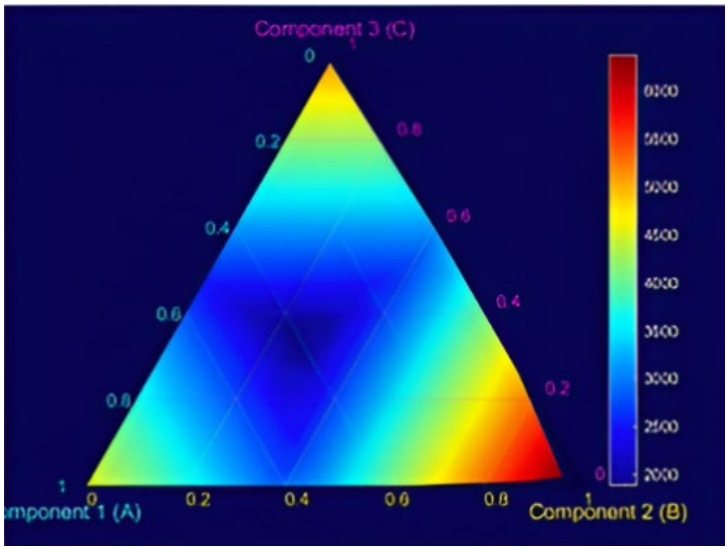

Figure 4. Limonen (A), Geraniol (B), Vanilin (C)

This illustration then changes when the compound is dissolved in mineral oil, as shown in the diagram on the right. Iso-e-super, which was originally present in the aroma mapping, becomes unmapped. The non-perpendicular color boundaries observed in the PTD also indicate multicomponent systems commonly exhibit non-ideal behavior. Geraniol contains a hydroxyl group capable of intermolecular hydrogen

interactions, while iso-e-super and hebanolide are more hydrophobic and less polar. These polarity differences affect molecular packing within the liquid phase and alter the partial vapor pressure of each compound. Mineral oil acts as a non-volatile liquid phase with very low vapor pressure, reducing the overall evaporation rate of fragrance molecules by increasing solvation and decreasing molecular diffusion toward the interface. This shifts the vapor–liquid equilibrium toward retention in the liquid phase, especially for heavier compounds such as hebanolide. Consequently, volatility differences among the aroma compounds become less pronounced, leading to a more uniform PTD distribution pattern. Nevertheless, geraniol remains dominant because its vapor pressure and odor activity are still sufficiently high to maintain significant partitioning into the gas phase even in the presence of solvent retention effects.

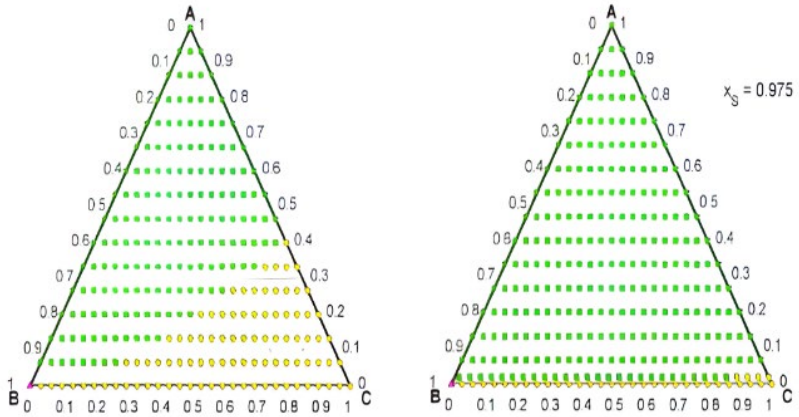

Figure 5. Geraniol (A, Green), Hebanolide (B, Pink), Iso-E-Super (C, Yellow)

Now we move to matrix consisting of alpha-pinene, linalool, and vanillin dissolved in ethanol [21]. An illustration of this mapping is shown in **Figure 6**. The diagram on the left maps three different aromas under ideal conditions, while the diagram on the right map's aromas under non-ideal conditions. Increasing ethanol levels, both in ideal and non-ideal solutions, indicate changes in the aroma region mapping of each component. The more ethanol in the matrix, the position and extent of the dominance zone will shift. This is because each component will change its diffusion and volatility behavior when the ethanol solvent is higher. A significant difference is found at 70% ethanol concentration, where in the ideal solution, the diagram region map is filled entirely by ethanol. Meanwhile, in the non-ideal solution, the dominant region mapping is still indicated by alpha-pinene (annotated by a square). This difference can occur because in an ideal solution, intermolecular interactions do not occur. Increasing the ethanol composition will increase the OV of ethanol. Meanwhile, in a non-ideal solution, molecular interactions occur between compounds. Alpha-pinene and ethanol have different polarities. Under non-ideal conditions, due to low solubility, much alpha-pinene is 'rejected' (antagonistic effect) from the matrix so that the compound is easily pushed out into the headspace and dominates the aroma.

A similar finding was also described by matrix Limonene, geraniol, vanilin.[22]. An illustration of the mapping is shown in **Figure 7**. Aroma mapping shows that all compounds are present, forming a system character dominated by limonene (annotated by a square). However, the addition of ethanol shows a shift in the position of geraniol and vanillin by ethanol. As ethanol is added more, geraniol and vanillin are increasingly underrepresented. This prediction is then compared with experimental data at three different composition ratios. These three compositions show the highest OV possessed by limonene. This is confirmed by smelling the perfume and obtaining a strong lemon aroma. From the experimental data of these three compositions, it is known that the OV values are well predicted by PTD. A different situation occurs for vanillin, where the experimental OV data shows a value much higher than the simulated one. In the simulation, the OV of vanillin is in the range of 20-30%. In reality, the experimental results show the OV of vanillin is in the range of 70-700% where the OV of vanillin at low limonene concentrations is also reduced. This means that limonene and vanillin have a molecular interaction that causes vanillin evaporation to be increased by the presence of limonene at relatively high concentrations. This phenomenon confirms that the integration of OV into PTD can map

the influence of OV changes on the aroma character of the matrix well.

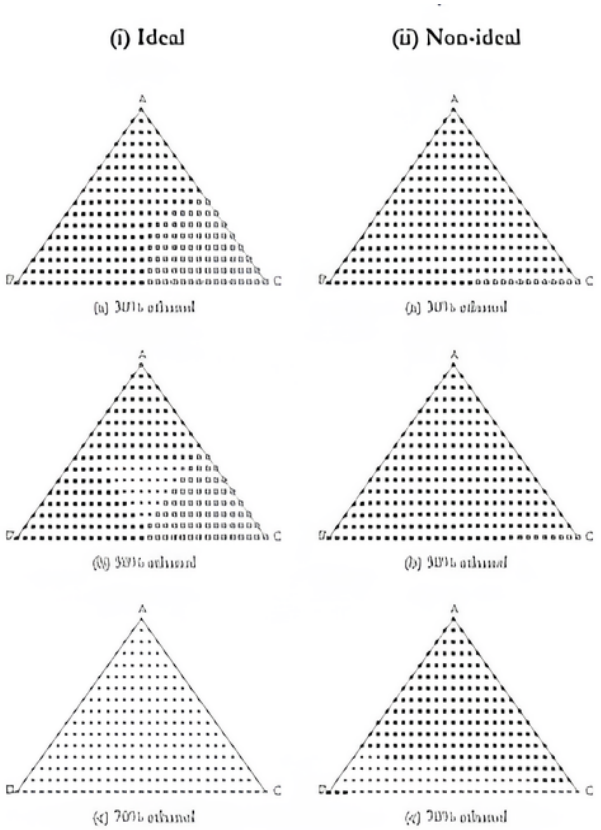

Figure 6. Alpha pinene (A), Linalool (B), Vanilin (C).

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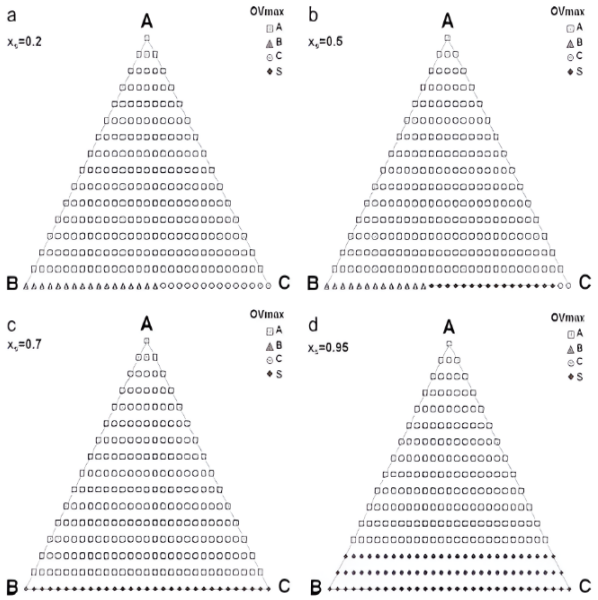

Figure 7. Limonene (A), Geraniol (B), Vanilin (C).

The integration of odor value (OV) into the Perfume Ternary Diagram (PTD) shows that the aroma dominance map is a representation of the effective OV of each component under certain matrix conditions. This integration plays a direct role in determining the aroma mapping pattern, thus providing information on aroma dominance, component diffusion in the matrix, and the influence of solvents in the matrix. Changes in OV, whether due to variations in material composition, physical properties of solvents, or non-ideal intermolecular interactions, will change the volatility between components and ultimately shift the dominance region in the diagram. When the OV of a component increases, its influence zone in the PTD tends to widen. Conversely, a decrease in OV causes a narrowing of the region or a shift in dominance. This phenomenon indicates that the OV value determines the potential for aroma dominance, but aroma mapping in the Perfume Ternary Diagram shows that aroma realization is highly dependent on the physicochemical properties of the matrix. Aroma mapping in pure conditions follows the calculated OV pattern: the higher the OV, the more dominant the aroma. However, actual volatility is strongly influenced by the type of solvent (polarity) and molecular interactions in the matrix

CONCLUSION

Based on the results of the review that has been conducted, it can be concluded that the Odor Value (OV) approach on aroma analysis is principally influenced by the concentration of compounds in the headspace, odor threshold value, activity coefficient, and molecular interactions. The odor value approach can be used in complex matrix by calculating the OV involving the physicochemical properties of each component and molecular interaction between component by calculating a_{mn}parameter use UNIFAC model. The odor value approach also can be used in Perfumery Ternary Diagram because this integration plays a direct role in determining the aroma mapping pattern, thus providing information on aroma dominance, component diffusion in the matrix, and the influence of solvents in the matrix. Changes in OV, whether due to variations in material composition, physical properties of solvents, or non-ideal intermolecular interactions, will change the volatility between components and ultimately shift the dominance region in the diagram. The use of OV in aroma analysis and aroma mapping has advantages, including: OV allows identification of the contribution of each volatile compound to the overall aroma based on the odor threshold value. Moreover, this advantage can be used when we formulating fragrance because components with low sensory impact can be eliminated, resulting in a more material-efficient, stable, and consistent formulation, and supporting green chemistry practices through optimizing the use of strong-scented ingredients, which directly reduces the carbon footprint and resource consumption. This is in line with the International Fragrance Association (IFRA) regulations that emphasize safety and environmental responsibility in the selection of fragrance ingredients.

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