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► To cite this version:

Nico Lippi, Elisa Senger, Saila Karhu, Bruno Mezzetti, Marta Cianciabella, et al.. Development and Validation of a Multilingual Lexicon as a Key Tool for the Sensory Analyses and Consumer Tests of Blueberry and Raspberry Fruit. *Agriculture*, 2023, 13 (2), pp.314. 10.3390/agriculture13020314 . hal-04050509

HAL Id: hal-04050509

<https://hal.inrae.fr/hal-04050509>

Submitted on 29 Mar 2023

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Article

Development and Validation of a Multilingual Lexicon as a Key Tool for the Sensory Analyses and Consumer Tests of Blueberry and Raspberry Fruit

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Citation: Lippi, N.; Senger, E.; Karhu, S.; Mezzetti, B.; Cianciabella, M.; Denoyes, B.; Sönmez, D.A.; Fidelis, M.; Gatti, E.; Höfer, M.; et al. Development and Validation of a Multilingual Lexicon as a Key Tool for the Sensory Analyses and Consumer Tests of Blueberry and Raspberry Fruit. *Agriculture* **2023**, *13*, 314. <https://doi.org/10.3390/agriculture13020314>

Academic Editor: Maria Teresa Frangipane

Received: 7 December 2022

Revised: 12 January 2023

Accepted: 21 January 2023

Published: 28 January 2023



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Abstract: A comprehensive lexicon is a necessary communication tool between the panel leader and panelists to describe each sensory stimulus potentially evoked by a product. In the current scientific breeding and trading scenario, a multilingual sensory lexicon is necessary to ensure the consistency of sensory evaluations when tests are conducted across countries and/or with international panelists. This study aimed to develop a reference multilingual lexicon for raspberry (*Rubus idaeus* L.) and blueberry (*Vaccinium corymbosum* L.) to perform comparative sensory tests through panels operating in different countries using their native language. Attributes were collected from state-of-the-art literature and integrated with a detailed description of the sensory stimulus associated with each term. A panel of sensory judges was trained to test lexicon efficacy. After training, panelists evaluated three cultivars of blueberry and raspberry through RATA (Rate All That Apply), which allowed missing attributes to be excluded while rating those actually present. Results showed the discerning efficacy of the lexicon developed can be a valuable tool for planning sensory evaluations held in different countries, opening up further possibilities to enrich blueberry and raspberry descriptor lists with emerging terms from local experience and evaluations of berry genotypes with peculiar traits.

Keywords: berry; sensory lexicon; sensory evaluation; RATA; multilingual lexicon

1. Introduction

Sensory analysis is aimed at capturing all product characteristics through a comprehensive evaluation of the product's perceptible attributes and their relative intensities. When applied to foods, the core of this discipline is the knowledge of human perception of taste, odor, sound, mouthfeel and visual stimuli [1]. A basic requisite of sensory analysis is to define all the possible terms useful for describing all perceived stimuli and assess similarities and differences among products. Sensory analysis guidelines accurately define the figure of the sensory scientist (panel leader) [2] possessing the appropriate expertise in this field, knowledge about sensory methodologies, and communication skills necessary for efficaciously training the sensory judges. Panelists should be trained to exploit individual perception ability, and to properly communicate, with precise terms, characteristics and intensity of their sensations.

A shared lexicon is a necessary communication tool, between a panel leader and panelists, providing the correct terms for describing each sensory stimulus. The sensory lexicon is defined as a "standardized vocabulary" [3], and it is an essential prerequisite for conducting a descriptive sensory analysis. The current distribution of sensory lexica has been reviewed by [4], and indicated the importance of increasing the availability of this essential support for a sound sensory evaluation of products. A multilingual sensory lexicon is necessary to assure the consistency of evaluation when tests are conducted across countries and/or when the participants of a sensory test speak different languages. Studies have been reported for snacks with matching translations in English, Spanish, Chinese, and Hindi [5], for kimchi cabbage in English and Korean [6], and for Sichuan pepper in English and Chinese [7].

Lawless and Civille, 2013 assigned the lexicon development procedure to highly-trained panelists, describing their individual perceptions of products and confirming them in a consensus session. However, increasing availability of literature and the development of rapid methodologies such as CATA (Check-All-That-Apply) and RATA (Rate-All-That-Apply) [8] allow sensory specialists to choose terms and propose them to trained panelists only for validation and, eventually, integration of an attribute list. RATA, highlighting a selection of comprehensive perceivable sensations, fits the attributes list validation process perfectly and reduces judges' fatigue as compared to descriptive analysis, which requires the explicit intensity assessment of all listed attributes [9,10]. This approach reduces the development time while maintaining high accuracy [10].

The novel study conducted here was implemented within the framework of the Horizon2020 project BreedingValue [11], which includes, among other activities, panel and consumer sensory evaluations of berries in different European countries in order to assess the consumer perception of a wide range of genetic resources, spanning from new pre-breeding material to established cultivars.

Since a strawberry (*Fragaria × ananassa* Duch.) lexicon was already developed and a specific 16-term lexicon was available [12], our research focused on raspberry (*Rubus idaeus* L.) and blueberry (*Vaccinium corymbosum* L.), both still lacking an exhaustive lexicon. Indeed, despite the growing interest in the production, trade and consumption of blueberries and raspberries, the bibliographical research evidenced the relatively low number of papers providing information on blueberry and raspberry sensory evaluation. Such a limited bibliography was not a sufficient precondition to develop a complete lexicon to be translated into different languages. Thus, the aim of this research was to develop a standard multilingual lexicon for berries, to provide panel leaders and assessors in different countries with a standard tool for performing comparative sensory tests for evaluating the same attributes but using their native language. The activity was designed to (a) develop a comprehensive sensory lexicon; (b) translate the sensory terms and definitions from English into six other languages: Finnish, French, German, Italian, Spanish, Turkish; and (c) validate the lexicons' adequacy and effectiveness by a trained panel. The lexicons' validation was executed by a trained panel using RATA, allowing the use of a high number of descriptors, rating only those actually perceived, thus reducing so-called sensory fatigue [9,10].

2. Materials and Methods

2.1. Collection of Sensory Terms

The first step was collecting and selecting sensory attributes used in scientific literature, aiming to cover a high range of sensory stimuli provoked by blueberry and raspberry fruit. The literature research was carried out in Scopus, Web of Science and Google Scholar platforms by using the following keywords: Blueberry, Raspberry, Blueberry sensory evaluation, Raspberry sensory evaluation.

2.2. Expert Consultation and Translation of Lexicons

The first versions of the blueberry and raspberry lexicons were created in English, and further analyzed and commented by a multi-national panel of sensory experts, participating in the BreedingValue project. The sensory evaluation lists of terms were chosen through a comprehensive literature review and implemented with the contribution of sensory scientists' previous work and experience. Once consensus about sensory attributes to be included alongside a relative description had been achieved, each partner translated it into their native language. The aim was to create a 7-language sensory lexicon including English, Italian, Finnish, French, German, Turkish and Spanish.

2.3. Sensory Evaluation Tests to Validate Lexicons

The sensory evaluation tests were performed at the IBE (Institute of Bioeconomy) sensory laboratory (Bologna, Italy), under controlled environmental conditions with individual, fully-equipped sensory booths. Fizz software (Version 2.51 c02; Biosystèmes, Couternon, France) was used for data collection. Visual aspects (color, size, shape, peculiar features) of fruit were not submitted to panelists in the validation process, since they can be measured through laboratory technology (e.g., colorimetry, image analysis).

2.4. Samples

The blueberry cultivars AtlasBlue, Rebel and Ventura, and the raspberry cultivars Adelita, Dafne and Lagorai Plus, supplied by Sant'Orsola S.C.A. (Italy), were used for the lexicon validation tests (Figure 1). Samples, at commercial ripeness, were collected from fields in Sicily and shipped in a refrigerated truck ($4\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$) to Sant'Orsola SCA headquarter (Cirè di Pergine Valsugana (TN), Italy), stored at $1.5\text{ }^{\circ}\text{C} \pm 0.5\text{ }^{\circ}\text{C}$ for 2 days, and delivered to IBE laboratory for sensory test evaluations conducted at room temperature ($22\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$).

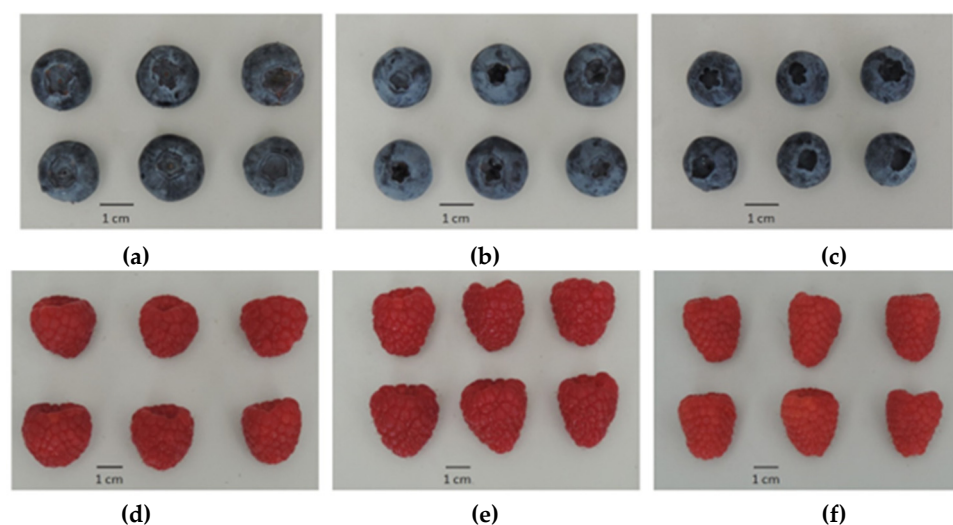


Figure 1. Cultivars used for sensory evaluation. Blueberry: (a) cv. AtlasBlue, (b) cv. Rebel, (c) cv. Ventura. Raspberry: (d) cv. Adelita, (e) cv. Dafne, (f) cv. Lagorai Plus.

2.5. Panelists

Two trained panels (16 judges for blueberry and 14 for raspberry) were involved in the sensory testing. The chosen panelists had more than 1000 h of experience in general sensory tasting for various food and sensory techniques, including attribute identification. Moreover, they had completed 100 h training on fruit-related attributes.

2.6. RATA Analysis

The panel leader explained each sensory descriptor to the panelists to upskill them on the lexicon-sorting step. Lexicon sorting was performed through the RATA sensory test [10]. The RATA evaluation sessions lasted 45 min, and two replicas were performed for each berry species. Panelists received a sample set consisting of the three cultivars, three fruits per cultivar, coded by a three-digit code, for each berry species. The presentation order of the samples was randomized among panelists using a balanced Latin square design. The order of attributes was randomized by sensory modality (texture, taste and flavor). Panelists were asked to taste each sample and check the sensory features perceivable among the list. First, the term was checked and, if applicable, the intensity perceived was indicated through a 9-point scale from “low” to “high”. Instead of a 3- or 5-point scale, this was used to improve the discriminability of subtle differences [13]. After each sample, the panelists waited for 60 s to be prepared for the next evaluation and rinsed their mouths with mineral water. Judges selected and rated the attributes perceived in the tested samples, while discarding those not identified.

2.7. Statistical Analysis

Statistical analysis was performed using *SPSS* software (IBM Corp. Released 2021. IBM SPSS Statistics for Windows, Version 28.0, IBM Corp, Armonk, NY, USA). The RATA data were analyzed through two approaches: the first considered the frequency selection of terms (RATA frequencies), and the second considered the data as RATA intensities [13]. RATA frequencies were calculated by counting the number of citations for each attribute. A contingency table was built from the RATA data. According to relative frequency, the list of attributes was divided into tertiles. For each sample, only attributes belonging to the third (67–100% frequency) and second (34–66%) tertiles were used to create a Venn diagram showing the attributes shared by the three cultivars analyzed in the given berry species. The Venn diagram was computed using *R* software version 4.2.2 (R Core Team, 2022). RATA intensities were interpreted on a 10-point scale; not cited terms were scored as “0”, thus, a non-selected term was considered equivalent to the “not perceivable” label (intensity = 0). A two-way ANOVA model (product and replicate) was applied to RATA intensity scores, only on attributes already selected for the Venn diagram (second and third citation tertile). A Tukey’s post hoc test was calculated to test the differences between cultivars with the significance level fixed at $p < 0.05$. Mean RATA intensity values were used to generate a spider plot representing the sensory profiles of each cultivar.

3. Results

3.1. Sensory Terms Literature Research and Selection

3.1.1. Sensory Descriptors for Blueberry

In earlier reports, blueberry has been described as “fresh fruit” by Rosenfeld et al. [14], providing a list of selected sensory attributes, and as “juice” [15] with a particular focus on its flavors. Furthermore, blueberry texture has been investigated through sensory analysis, focusing on crispness [16]. For blueberry, we selected 29 terms: 17 descriptors for flavor (berry, blueberry, citrus, earthy/musty, fermented, floral, fruity, grassy, green, minty, overripe fruit, pungent, acid, spicy, strawberry, sweet, watery), three for taste (sweet, acid, bitter), eight to chemesthesis/mouthfeel (astringent, fibrous, firm, juicy, metallic, skin persistence, seedy, throat burn), and freshness as a typical fruit metadescriptor [17] (Table 1). Each attribute was described in seven languages, to allow panelists’ and consumers’ evaluations in their native language, while maintaining the original meaning (Table 2).

Table 1. Blueberry sensory attributes in English, Finnish, French, German, Italian, Spanish and Turkish (References: ^a: Bett-Gaber and Lea, 2013 [15]; ^b: Ferrao et al., 2020 [18]; ^c: Gilbert et al., 2015 [19]; ^d: Cheng et al., 2020 [20]; ^e: Rokayya et al., 2020 [21]; ^f: Asănică, 2018 [22]; ^g: Peneau et al., 2007 [17]; ^h: Rosenfeld et al., 1999 [14]; ⁱ: Sater et al., 2021 [23]; ^{BPE}: BreedingValue Project Experts).

| ENGLISH Attributes Appearance | FINNISH Kuvaajat Ulkonäkö | FRENCH Attributs Apparence | GERMAN Attributs Aussehen | ITALIAN Attributi Apparenza | SPANISH Atributo Apariencia | TURKISH Özellikler Görünüm |
|--|-----------------------------|----------------------------|-----------------------------|-----------------------------|-----------------------------------|------------------------------------|
| Skin colour ^{e,f,h} | Pinnan väri | Couleur de la peau | Äußere Farbe der Frucht | Colore della buccia | Color de la piel | Dış renk |
| Size ^f | Koko | Taille | Größe | Dimensioni | Tamaño | İriliik |
| Uniformity of size ^{BPE} | Koon tasaisuus | Homogénéité de calibre | Einheitlichkeit der Größe | Uniformità di dimensione | Uniformidad de tamaño | İriliğin bir örnek olma durumu |
| Pruine ^{BPE} | Vahapintaisuus | Pruine | Ausprägung der Wachsschicht | Pruina | Pruina | Mumsu görünüm |
| Glossiness ^e | Kiiltävyys | Brillance | Glanz | Lucentezza | Brillo | Parlaklık |
| Flavor | Aromi/Flavori | Arôme/Saveur | Aroma | Aroma | Aroma/olor | Koku/Lezzet |
| Acid ^a | Hapan aromi | Acide | Sauer | Acido | Aroma ágrico | Ekşi aroma |
| Berry ^a | Marjainen | Petits fruits | Beere | Piccoli frutti | Baya | Karışık meyveler |
| Blueberry ^{a,b,c,f,h,i} | Pensasmustikka | Myrtille | Heidelbeere | Mirtillo | Arándano | Mavi yemiş |
| Citrus ^a | Sitrus | Citrus | Zitrus | Agrumi | Ágrico/Citrico | Narenciye |
| Earthy/musty ^{a,h} | Maa | Terre/Moisi | Erdig/Muffig | Terroso | Terroso | Toprak/Küf |
| Fermented ^a | Fermentoitu | Fermenté | Fermentiert/Vergoren | Fermentato | Fermentado | Fermente |
| Floral ^{a,d} | Kukkainen | Floral | Blumig | Floreale | Floral | Çiçeksi |
| Fruity ^d | Hedelmäinen | Arôme Fruité | Fruchtig | Fruttato | Afrutado | Meyvemsi |
| Grassy ^d | Ruohoinen | Herbacé | Grasig | Erba | Hierba | Otsu |
| Green ^{a,i} | Vihreä | Vert/tiges | Grün/Stengel | Verde | Verde / Tallos | Yeşil/odunsu |
| Minty ^d | Minttu | Menthe | Minzig | Menta | Menta | Naneli |
| Overripe fruit/straw-like ^a | Ylikypsä hedelmä/olkimainen | Fruit surmature/paille | Überreifes Obst/Strohartig | Frutto sovramaturo/paglia | Sobremaduro | Aşırı olgunlaşmış meyve/saman gibi |
| Pungent ^a | Pistävä | Piquant/Acre | Scharf | Pungente | Aroma ocre/pungente | Keskin aroma |
| Spicy ^d | Mausteinen | Piquant | Würzig | Speziato | Picante/Espeziado | Baharatlı |
| Strawberry ^a | Mansikka | Fraise | Erdbeere | Fragola | Fresa | Çilek |
| Sweet ^a | Makea aromi | Sucré/Doux | Süßes Aroma | Dolce | Aroma dulce | Tatlı aroma |
| Watery ^{BPE} | Vetinen | Goût d'eau | Wässrig | Acquoso | Aroma a aguado | Sulu lezzet |
| Taste | Perusmaku | goût | Geschmack | Gusto | Sabor | Tat |
| Acid ^{a,b,c,h,i} | Hapan | Acide | Säuerlicher Geschmack | Acido | Ágrico | Ekşi |
| Bitter ^{a,h} | Karvas | Amer | Bitterer Geschmack | Amaro | Amagor | Acı |
| Sweet ^{a,b,c,h,i} | Makea | Sucré | Süßer Geschmack | Dolce | Dulce | Tatlı |
| Texture/mouthfeel | Rakenne/Suutuntuma | Texture/Texture En Bouche | Textur/Mundgefühl | Sensazione in bocca | Textura | Doku/Ağız hissi |
| Astringent ^a | Astringoiva | Astreingent | Adstringierend | Astringenza | Astringencia | Buruk veya ekşilik |
| Fibrous ^{BPE} | Kuituinen | Fibreux | Faserig | Fibrosità | Fibrosidad | Lifi |
| Firm ^{e,f,h,i} | Kiinteä | Ferme | Festigkeit | Durezza | Durezza | Sert |
| Metallic ^a | Metallinen | Métallique | Metallisch | Metallico | Metálico | Metallik |
| Juicy ^{f,h} | Mehukas | Juteux | Saftigkeit | Successità | Jugosidad | Sultuluk |
| Seedy ^{BPE} | Siemeninen | Riche en graines | Samenreich | Presenza di semi | Presencia de semillas | Çekirdekliklik |
| Skin persistence ^{BPE} | Kuoren sitkeys | Persistence de la peau | Persistenz der Haut | Buccia persistente | Persistencia de la piel | Meyve dış kabuk dayanıklılığı |
| Throat burn ^a | Kurkkua polttava | Brûlure de la gorge | Brennen in der Kehle | Pungenza | Sensación de ardor en la garganta | Boğaz yakan |
| Metadesciptor | Yleiskuvas | Metadesciptor | Metadesciptor | Metadescrittore | Metadesciptor | Meta tanımlayıcı |
| Freshness ^g | Tuoreus | Fraîcheur | Frische | Freschezza | Frescura | Tazelik |

3.1.2. Sensory Descriptors for Raspberry

Relatively few studies have investigated the sensory properties of raspberry [24,25]. Studies of raspberry odor-active compounds have determined that the most important was raspberry ketone (4-(4-hydroxyphenyl)-butane-2-one) and *aaL*- and *βbT*-ionone, with linalool and geraniol peculiar to some of the tested varieties [26]. In our study, 29 terms were selected for raspberry: 19 attributes for flavor (acid, berry, caramel, chemical, citrus, cloying, fermented, floral, fruity, grassy, green, green/tomato, minty, nutty, raspberry, sweet, tropical fruit, watery, woody), three related to taste (sweet, acid, bitter), six to chemesthesis/mouthfeel (astringent, metallic, juicy, fibrous, firm, seedy), and freshness as a typical fruit metadesciptor [17] (Table 3). Each attribute was again described in seven languages to allow panelists' and consumers' evaluations in their native language, while maintaining the original meaning (Table 4).

Table 2. Descriptions of blueberry sensory attributes in English, Finnish, French, German, Italian, Spanish and Turkish.

| Attributes Appearance | ENGLISH Description Appearance | FINNISH Kuvaus Ulkonäkö | FRENCH Description Apparence | GERMAN Beschreibung Aussehen | ITALIAN Descrizione Apparenza | SPANISH Descripción Apariencia | TURKISH Özellikler Görünüm |
|-----------------------|---|---|---|---|---|--|--|
| Skin colour | Blue colour intensity evaluation | Sinisen värin tummuus | Évaluation de l'intensité des couleurs bleues | Bewertung der Farbintensität | Valutazione dell'intensità di blu | Evaluación de la intensidad del color azul | Mavi renk yoğunluğu değerlendirmesi |
| Size | Berry dimension evaluation | Marjan koko arvioituna | Évaluation de la dimension des baies | Bewertung der Beerengröße | Valutazione delle dimensioni del frutto | Evaluación del tamaño del fruto | Meyve boyut değerlendirmesi |
| Uniformity of size | Uniformity size between the single fruit | Koon tasaisuus | Taille uniforme entre les fruits | Einheitliche Größe zwischen den einzelnen Früchten | Dimensione uniforme tra i frutti | Uniformidad de tamaño entre el fruto | Meyve iriliğinde bir örneklik durumu |
| Pruine | Waxy layer detection on the fruit surface | Pinnan vahakerroksen voimakkuus | Détection d'une couche cireuse à la surface du fruit (pruine) | Bewertung der Ausprägung der Wachsschicht auf der Oberfläche | Valutazione dalla presenza di patina cerosa superficiale | Detección de una capa de ceras sobre la superficie | Meyve yüzeyinde mumlu tabaka oluşumu |
| Glossiness | Brightness evaluation of the fruit | Marjan pinnan kiiltävyyys | Évaluation de la brillance du fruit | Bewertung des Glanzes der Frucht | Valutazione della lucentezza del frutto | Evaluación del brillo del fruto | Meyvenin parlaklık durumu |
| Flavor | Flavor | Aromi/Flavori | Arôme/Saveur | Aroma | Aroma | Aroma/Olor | Koku/Lezzet |
| Acid | A sharp flavor associated with products that have a sour taste | Terävä, hapantuotteeseen liittyvä aromi | Arôme âcre associé à des produits ayant un goût acide | Ein beißendes Aroma in Verbindung mit Produkten, die einen sauren Geschmack haben | Aroma forte associato a prodotti che hanno un sapore acido (acidi organici) | Aroma asociado a productos ágricos | Eksi bir tada sahip olma hissi veren keskin bir aroma |
| Berry | Flavor associated with a combination of mixed berries | Marjojen, marjasekoitusten aromi | Arôme associé à une combinaison de petits fruits (fruits rouge) | Aromen, die mit einer Kombination von gemischten Beeren assoziiert werden | Sensazione aromatica associata ai piccoli frutti (fragola, lampono, mirtillo, mora) | Aroma asociado a una mezcla de bayas, pequeños frutos (frutos rojos) | Karışık meyve kombinasyonu hissi veren aroma |
| Blueberry | Flavor associated with fresh blueberries | Tuoreen pensasmustikan aromi | Arôme associé aux bleuets frais | Aromen, die mit frischen Heidelbeeren assoziiert werden | Sensazione aromatica associata ai mirtilli | Aroma asociado al arándano fresco | Taze Mavi yemişi hissi veren aroma |
| Citrus | Flavor associated with citrus fruit (ex. lemon, orange, lime) | Sitruhedelmän aromi (esim. sitruuna, appelsiini, lime) | Arôme associé aux agrumes (ex. citron, orange, citron vert) | Aromen, die mit Zitrusfrüchten assoziiert werden (z. B. Zitrone, Orange, Limette) | Sensazione aromatica associata ad agrumi (ex. Limone, Arancia, Lime) | Aroma asociado a los cítricos (ej. limón, naranja, lima) | Narenciye türlerini anımsatan aroma (portakal, limon vs.) |
| Earthy/musty | Flavor associated with soil (ex. red beet, boiled potato, or mushrooms) | Maaperään liittyvä aromi (esim. punajuuri, keitetty peruna, sien) | Arôme associé à la terre (ex. betterave rouge, pomme de terre bouillie, ou champignons) | Aromen, die mit Erde assoziiert werden (z. B. rote Beete, gekochte Kartoffeln oder Pilze) | Sensazione aromatica associata con il suolo(ex. Rapa, Patata bollita o funghi) | Aroma asociado a suelo/tierra (ej. Remolacha roja, patata cocida, champiñón/setas) | Toprağı anımsatan aromalar (ör. kırmızı pancar, haşlanmış patates veya mantar) |
| Fermented | Flavor associated with fermented /rotting fruit or vegetable | Käyneen, pilaantuneen hedelmän tai vihanneksen aromi | Arôme associé à un fruit ou un légume fermenté ou pourri | Aromastoffe, die mit fermentiertem/faulendem Obst oder Gemüse assoziiert werden | Sensazione aromatica associata con frutta o verdura fermentata/marcia | Aroma asociado a la fermentación y la fruta podrida | Fermente/çürüyen meyve veya sebze hissi veren aroma |
| Floral | Sweet flavor sensation associated with flowers | Kukkiin liittyvä makea aromi | Arôme associé aux fleurs | Süßes, aromatisches Empfinden, das mit Blumen assoziiert werden kann | Sensazione aromatica associata ai fiori | Sensación aromática dulce asociada a las flores | Çiçek kokusunu anımsatan tatlı aromatik his |
| Fruity | Sweet, intense flavor associated with a combination of mixed fruit | Hedelmiin liittyvä makea aromi | Arôme doux et intense associé à un mélange de fruits | Süßes, intensives Aroma, das mit einer Kombination aus gemischten Früchten assoziiert werden kann | Intensa sensazione aromatica dolce associata al mix di frutta fresca | Aroma dulzón, intenso, asociado a una mezcla de frutos | Karışık meyve kombinasyonunu anımsatan tatlı, yoğun aroma |

Table 2. Cont.

| Attributes Appearance | ENGLISH Description Appearance | FINNISH Kuvaus Ulkonäkö | FRENCH Description Apparence | GERMAN Beschreibung Aussehen | ITALIAN Descrizione Apparenza | SPANISH Descripción Apariencia | TURKISH Özellikler Görünüm |
|---------------------------|--|--|--|---|---|---|--|
| Grassy | Grassy and leafy-like flavor | Ruohoihiin, lehtiin liittyvä aromi | Arôme d’herbe fraîchement coupée | Aroma das Bezieht sich auf durch geschnittenes Gras | Sensazione aromatica, erba appena tagliata o foglie | Aroma asociado a la hierba verde, hoja | Yeşil çimen ve yaprak benzeri aromaları anımsatan aroma |
| Green | Flavor characterizing unripe green fruit | Raakoihin hedelmiin liittyvä aromi | Arôme d’un fruit non mûr (vert) | Ein unreifes Aroma das unreife, grüne Früchte. | Sensazione aromatica associata ai frutti immaturi | Un aroma a inmaduro, característico, la fruta verde inmadura | Olgunlaşmamış meyveleri aroma |
| Minty | Refers to the minty flavor and cooling sensations | Minttuun, viilentävään tuntemukseen liittyvä aromi | Arôme de menthe qui donne une sensation rafraîchissante | Bezieht sich auf minzige und kühlende Aromen | Sensazione riferita ad aroma di menta, una sensazione di fresco | Aroma mentolado y de sensaciones refrescantes | Soğuk hissi veren nane benzeri aroma |
| Overripe fruit/straw-like | Flavor associated with overripe or bruised fruit. Reminiscent of straw aroma | Ylikypsiin hedelmiin, olkeen liittyvä aromi | Arôme de fruits trop mûrs. Rappelle l’arôme de paille | Aroma, das mit überreifen oder gequetschten Früchten assoziiert werden kann erinnert an das Aroma von Stroh | Aroma associato con frutti sovramaturi, ricorda la paglia | Aroma asociado con fruto sobremaduro/dañado. Aroma con reminiscencias a la paja | Aşırı olgunlaşmış veya çürümüş meyvelerilanımsatan aroma Samanı anımsatan aroma |
| Pungency | Burning sensation in nasal cavity associated with balsamic or red-wine vinegar | Nenässä pistävä, etikkainen tuntuma | Sensation de brûlure dans la cavité nasale associée au vinaigre balsamique ou au vin rouge | Ein brennendes Gefühl in der Nasenhöhle in Verbindung mit Balsamico- oder Rotweinessig | Sensazione di bruciore nella cavità nasale associata ad aceto balsamico o aceto di vino rosso | Sensación de ardor en la cavidad nasal asociada con los vinagres de vinos tintos o balsámicos | Balzemik veya kırmızı şarap sirkesini anımsatan burun boşluğunda yanma hissi yapan aroma |
| Spicy | Refers to the clove-like, balsamic and other spices-like flavour | Neilikkaan, balsamicoon, muihin mausteisiin viittaava aromi | Arôme faisant référence aux clous de girofle, au balsamique et à d’autres épices | Bezieht sich auf das Aroma von Gewürznelken, Balsamico und anderen gewürzartigen Aromen | Aroma riferito ai chiodi di garofano, balsamico o altre spezie | Se refiere a los aromas a clavo, balsámico y a otras especias. | Karanfil benzeri, balzemik ve diğer baharatları anımsatan aromalar |
| Strawberry | Fruity flavor associated with fresh strawberries | Tuoreen mansikan aromi | Arôme associé à la fraise | Fruchtige Aromen in Verbindung mit frischen Erdbeeren | Sensazione aromatica associata alle fragole | Aroma típico a fresas frescas | Taze çileği anımsatan meyvemsi aroma |
| Sweet | A sweet impression such as cotton candy, caramel, vanilla or sweet fruity candy (not berry) that may appear in the flavor or aromatics | Makea, vaniljainen, makeisiin, makeaan tuoksuun liittyvä aromi | Arôme donnant une impression sucrée comme de la barbe à papa, du caramel, de la vanille ou des bonbons fruités | Ein süßer Geschmack wie Zuckerwatte, Karamell, Vanille oder süße Fruchtbonbons (keine Beeren), der im Aroma oder in der Duftnote auftreten kann | Sensazione aromatica associata al dolce come zucchero filato, caramello, vaniglia | Aroma asociado al algodón dulce, caramelo, vainilla, o caramelos afrutados (no a bayas o pequeños frutos) | Pamuk şeker, karamel, vanilya veya tatlı meyveli şeker (üzümsü meyveleri değil) anımsatan aroma. |
| Watery | Associated with watery flavor, tame, tasteless | Vetinen, laimea maku, mauton | Arôme associé au goût aqueux et, insipide | Assoziiert mit wässrig, mild | Flavour associato con un gusto acquoso, senza sapore | Asociado con sabor acuoso, soso, insípido | Sulanmış tatsız bir lezzet |
| Taste | Taste | Perusmaku | Goût | Geschmack | Gusto | Sabor | Tat |
| Acid | Related to the basic taste acid | Happoisuuden aiheuttama maku | goût associé à l’acide | Bezogen auf den Grundgeschmack sauer | Gusto associato con composti acidi | Sabor ácido | Ekşi tat |
| Bitter | Related to the basic taste bitter | Karvasaineiden aiheuttama maku | goût associé à la stimulation de la langue par un composé amer | Bezogen auf den Grundgeschmack bitter | Gusto associato con composti amari | Sabor amargo | Acı tat |
| Sweet | Related to the basic taste sweet | Sokerien tai makeutusaineiden aiheuttama maku | Goût associé à la stimulation de la langue par le sucre ou un édulcorant | Bezogen auf den Grundgeschmack süß | Gusto associato con zucchero o dolcificanti | Sabor dulce o azucarado | Tatlı tat |

Table 2. Cont.

| Attributes Appearance | ENGLISH Description Appearance | FINNISH Kuvaus Ulkonäkö | FRENCH Description Apparence | GERMAN Beschreibung Aussehen | ITALIAN Descrizione Apparenza | SPANISH Descripción Apariencia | TURKISH Özellikler Görünüm |
|-----------------------|--|--|--|---|---|---|--|
| Texture/mouthfeel | Texture/mouthfeel | Rakenne/suutuntuma | Texture/Texture En Bouche | Textur/Mundgefühl | Texture | Textura | Doku/Ağız hissi |
| Astringent | Feeling in the mouth characterized by drying; associated with the presence of tannins | Kutistava, kurova tai kuivaava tunne suussa; tanniinien aiheuttama | Sensation complexe résultant de la contraction des muqueuses de la bouche, similaire à la sensation de sécheresse, associée aux tanins | Gefühl im Mund, das durch Austrocknung gekennzeichnet ist; verbunden mit dem Vorhandensein von Tanninen | Sensazione in bocca di secchezza, associata con la presenza di tannini | Sensación compleja que resulta de la contracción de las mucosas de la boca, parecida a la sensación de sequedad, asociada a los taninos | Tanenlerin varlığından damakta hissedilen kuruma hissi |
| Fibrous | The degree to which fibres are perceived throughout mastication | Kuitujen aistimisen aste pureskeltaessa | Degré de perception des fibres pendant la mastication | Grad der Wahrnehmung von Fasern während des Kauens | Grado con cui sono percepite fibre durante la masticazione | Grado de percepción de fibras durante la masticación | Çiğneme boyunca liflerin algılanma derecesi |
| Firm | Force required to bring teeth together during the mastication | Purentaan tarvittava voima | Force nécessaire pour rapprocher les dents pendant la mastication | Kraftaufwand, der erforderlich ist, um die Zähne während des Kauens zusammenzubekommen | Forza necessaria per la masticazione | Fuerza necesaria para unir los dientes durante la masticación | Çiğneme sırasında dişleri bir araya getirmek için gereken kuvvet |
| Metallic | Metallic perception in the mouth | Metallinen aistimus suussa | Sensation métallique en bouche | Metallisches Gefühl im Mund (Geschmack) | Percezione metallica in bocca | Sensación metálica en boca | Damaktaki metalik algı |
| Juicy | The degree of juice presence | Mehupitoisuus | Quantité de jus dans le fruit | Grad des Vorhandenseins von Saft (Saftigkeit) | Grado di presenza di succo | Cantidad de jugo en el fruto | Düşükten yükseğe meyvenin sululuk derecesi |
| Seedy | The degree of seed perceived during the mastication | Pureskeltaessa havaittavat siemenet | Degré de présence des graines pendant la mastication | Der Grad der während des Kauens wahrgenommenen Samen | Semi percepiti durante la masticazione | El grado de presencia de aquenios durante la masticación | Çiğneme sırasında algılanan çekirdek algılama derecesi |
| Skin persistence | Coriaceous skin perceived on the mouth | Kuoren sitkeyden tunne suussa | Perception d'une peau coriace dans la bouche | Wahrgenommene lederige Haut im Mund | Buccia coriacea percepita in bocca | Percepción correosa de la piel del fruto en la boca | Meyve dış kabununun ağzıda hissedilmesi |
| Throat burn | Burning sensation perceived in the throat | Polttavan tunteen aistiminen kurkussa | Sensation de brûlure dans la gorge | Brennendes Gefühl im Rachen | Sensazione di bruciore percepita in gola | Sensación de quemazón en la garganta | Boğazda algılanan yanma hissi |
| Metadescriptor | Metadescriptor | Yleiskuvaaja | Metadescriptor | Metadeskriptor | Metadescrittore | Meta descriptor | Metadescriptor |
| Freshness | Meta-descriptor, satisfaction of mix features (appearance, textural, aromatic and tasting) | Yleiskuvaaja eri tekijöiden yhteisvaikutus huomioiden (ulkonäkö, rakenne, aromi, maku) | Méta-descripteur, satisfaction de la combinaison de toutes les caractéristiques (aspect, texture, arôme et goût) | Meta-Deskriptor, Zufriedenheit mit der Kombination aller Merkmale (Aussehen, Textur, Aroma und Geschmack) | Metadescrittore, soddisfazione di un mix di caratteristiche (apparenza, texture, aroma gusto) | Metadescriptor, satisfacción por la combinación de varias características (apariencia, textura, aroma y gusto) | Meta-tanımlayıcı, karışım özelliklerinin tatmini (görünüm, dokusal, aromatik ve tat) |

Table 3. Raspberry sensory attributes in English, Finnish, French, German, Italian, Spanish and Turkish. (References: ^a: Aaby et al., 2019, [24]; ^b: Zhang et al., 2021 [27]; ^c: Villamor et al., 2013 [28]; ^d: Stavang et al., 2015 [29]; ^e: Bett-Gaber and Lea, 2013 [15]; ^{BPE}: BreedingValue Project Experts).

| ENGLISH Attributes Appearance | FINNISH Kuvaajat Ulkonäkö | FRENCH Attributs Apparence | GERMAN Attribute Aussehen | ITALIAN Attributi Apparenza | SPANISH Atributo Apariencia | TURKISH Özellikler Görünüm |
|------------------------------------|---------------------------|----------------------------|--|-----------------------------|----------------------------------|----------------------------|
| Colour intensity ^{a,c} | Pinnan väri | Intensité de couleur | Intensität der Farbe | Intensità del colore | Intensidad del color | Renk yoğunluğu |
| Colour uniformity ^c | Värin yhtenäisyys | Uniformité de couleur | Gleichmäßigkeit der Farbe | Uniformità del colore | Uniformidad del color | Renk tekdüzeliği |
| Size ^{BPE} | Koko | Taille | Größe | Dimensione | Tamaño | İrilik |
| Shiny ^{BPE} | Kiiltävyys | Brillant | Glänzend | Lucentezza | Brillo | Parlaklık |
| Drupelet uniformity ^{BPE} | Drupelettien yhtäläisyys | Uniformité des drupelets | Einheitlichkeit der einzelnen Steinfrüchte | Uniformità delle drupeole | Uniformidad de las drupas | Küçük meyve birörnekliliği |
| Surface hairiness ^{BPE} | Pinnan nukkaisuus | Pilosité superficielle | Oberflächenbehaarung | Peluria superficiale | Vellosidad superficial | Yüzey tüylülüğü |
| Aroma/ Flavour | Aromi/ Flavori | Arôme/ Flaveur | Aroma | Aroma | Aroma/ Olor | Koku/ Lezzet |
| Acid ^a | Hapan aromi | Acide | Sauer | Acido | Aroma agrio | Ekşi lezzet |
| Berry ^{BPE} | Marjainen | Petits fruits | Beere | Piccoli frutti | Baya | Küçük meyve |
| Caramel ^b | Karamellisoitu | Caramel | Karamell | Caramello | Caramelo | Karamel |
| Chemical ^{a,b} | Kemikaali | Chimique | Chemisch | Chimico | Químico | Kimyasal |
| Citrus ^{BPE} | Sitrus | Citrus | Zitrus | Agrumi | Cítrico | Narenciye |
| Cloying ^a | Etova | Écoeurante | Unangenehm süßlich | Nauseante | Empalagoso | Mide bulandırıcı |
| Fermented ^{BPE} | Fermentoitu | Fermenté | Fermentiert/ Vergoren | Fermentato | Fermentado | Fermente |
| Floral ^{a,c} | Kukkainen | Floral | Blumig | Floreale | Floral | Çiçek |
| Fruity ^b | Hedelmäinen | Fruité | Fruchtig | Fruttato | Afrutado | Meyvemsi |
| Grassy ^b | Ruohoinen | Herbacé | Grasig | Erba | Herbal | Otsu |
| Green ^{a,c} | Vihreä | Vert | Grün | Verde | Verde | Yeşil lezzet |
| Green tomato ^{BPE} | Vihreä tomaatti | Tomates vertes | Grüne Tomate | Pomodoro verde | Tomate verde | yeşil domates |
| Minty ^{BPE} | Minttu | Menthe | Minzig | Menta | Menta | Nane |
| Nutty ^{BPE} | Pähkinäinen | Noisette | Nussig | Nocciola | Aroma a frutos secos | Fındık |
| Raspberry ^c | Vadelma | Framboise | Himbeere | Lampone | Frambuesa | Ahududu |
| Sweet ^{BPE} | Makea aromi | sucré/doux | Süßes Aroma | Aroma dulce | Aroma dulce | Tatlı aroma |
| Tropical fruit ^{BPE} | Trooppiset hedelmät | Arôme de fruit tropical | Tropische Früchte | Frutta tropicale | Frutas tropicales | tropik meyveler |
| Watery ^a | Vetinen | Goût d'eau | Wässrig | Acquoso | Aroma a aguado | Sulu lezzet |
| Woody ^b | Puu | Boisé | Holzig | Legnoso | Aroma a madera | Odunsu |
| Taste | Perusmaku | goût | Geschmack | Gusto | Sabor | Tat |
| Acid ^{a,c,d} | Hapan | Acide | Säuerlicher Geschmack | Acido | Acidez | Ekşi |
| Bitter ^{a,c,d} | Karvas | Amer | Bitterer Geschmack | Amaro | Amargor | Acı |
| Sweet ^{a,c,d} | Makea | Sucré | Süßer Geschmack | Dolce | Dulce | Tatlı |
| Texture/mouthfeel | Rakenne/Suutuntuma | Texture/ Texture En Bouche | Textur/ Mundgefühl | Sensazione in bocca | Textura | Doku/Agiz hissi |
| Astringent ^{a,c} | Astringoiva | Astringence | Adstringierend | Astringenza | Astringencia | Burukluk veya ekşilik |
| Fibrous ^{BPE} | Kuituinen | Fibreux | Faserig | Fibrosità | Fibrosidad | Liflilik |
| Firm ^{a,c} | Kiinteä | Fermeté | Fest | Durezza | Dureza | Sertlik |
| Metallic ^e | Metallinen | Métallique | Metallisch | Metallico | Metálico | Metalik |
| Juicy ^{a,c} | Mehukas | Juteux | Saftig | Succosità | Jugosidad | Sululuk |
| Seedy ^c | Siemeninen | Riche en graines | Samenreich | Presenza di semi | Sensación de semillas en la boca | Çekirdekliklik |
| Metadescriptor | Yleiskuvaaja | Metadescriptor | Metadeskriptor | Metadescrittore | Metadescriptor | Meta tanımlayıcı |
| Freshness ^d | Tuoreus | Fraîcheur | Frische | Freschezza | Frescura | Tazelik |

3.2. Sensory Evaluation

3.2.1. Blueberry Lexicon Sorting through RATA

Eight of the 29 attributes were in the third tertile (high frequency) of panel citation: blueberry flavor, acid taste, sweet taste, juicy, skin persistence, freshness, acid flavor and sweet flavor. Seven other attributes were used by a minimum of 34% of the panelists: firm, astringent, fibrous, floral, fruity, berry, and green, being thus part of the second tertile (medium frequency). Results showed that six attributes had a low frequency (peculiar traits), and five attributes were not used by the panelists to describe the berries (Table 5).

Table 4. Descriptions of raspberry sensory attributes in English, Finnish, French, German, Italian, Spanish and Turkish.

| Attributes Appearance | ENGLISH Description Appearance | FINNISH Kuvaus Ulkonäkö | FRENCH Description Apparence | GERMAN Beschreibung Aussehen | ITALIAN Descrizione Apparenza | SPANISH Descripción Apariencia | TURKISH Tanim Görünüm |
|-----------------------|---|--|--|---|--|---|--|
| Colour intensity | Intensity of the red colour of the fruit | Punaisen värin tumuus | Intensité de la couleur rouge du fruit | Intensität der roten Fruchtfarbe | Intensità del colore rosso | Intensidad del color rojo del fruto | Meyvenin kırmızı renginin yoğunluğu |
| Colour uniformity | Uniformity of the red colour across the fruit surface | Punaisen värin yhtenäisyys marjan pinnalla | Uniformité de la couleur rouge sur la surface du fruit | Gleichmäßigkeit der roten Farbe auf der Fruchtoberfläche | Uniformità del colore nella superficie del frutto | Uniformidad del color rojo en la superficie | Meyve yüzeyi boyunca kırmızı rengin tekdüzeliği |
| Size | Berry dimension evaluation | Marjan koko arvioituna | Évaluation de la dimension des baies | Bewertung der Fruchtgröße | Valutazione delle dimensioni del frutto | Evaluación del tamaño del fruto | Meyve boyut değerlendirilmesi |
| Shiny | Surface shining intensity | Pinnan kiillon voimakkuus | Intensité du brillant de surface | Glänzende Intensität der Oberfläche | Intensità di lucentezza superficiale | Intensidad superficial brillante | Yüzey parlama yoğunluğu |
| Drupelet uniformity | Drupelet shape and size uniformity | Drupelettien muodon ja koon tasaisuus | Uniformité de la forme Drupelet | Einheitlichkeit der Fruchtform | Uniformità della dimensione delle drupeole | Uniformidad de la forma drupelet | Küçük meyve şekli üniformitesi |
| Surface hairiness | Presence of the hair on the surface | Nukkakarvojen esiintyminen pinnalla | Présence du poil à la surface | Oberflächenbehaarung | Presenza di peluria superficiale | Presencia del cabello en la superficie | Yüzeyde kıllılık |
| Aroma/ Flavour | Aroma/ Flavour | Aromi/ Flavori | Arôme/ Flaveur | Aroma | Aroma | Aroma/ Olor | Koku/ Lezzet |
| Acid | A sharp flavor associated with products that have a sour taste | Terävä, hapantuotteeseen liittyvä aromi | Une saveur piquante associée à des produits qui ont un goût aigre/sûr | Ein beißendes Aroma in Verbindung mit Produkten, die einen sauren Geschmack haben | Aroma forte associato a prodotti che hanno un sapore acido (acidi organici) | Aroma asociado a productos ágricos | Ekşi bir tada sahip olma hissi veren keskin bir aroma |
| Berry | Flavor associated with a combination of mixed berries | Marjojen, marjasekoitusten aromi | Arôme associé à une combinaison de petits fruits (rouges) | Aroma in Verbindung mit einer Kombination von gemischten Beeren | Sensazione aromatica associata ai piccoli frutti (fragola, lampoene, mirtillo, mora) | Aroma asociado a una mezcla de bayas, pequeños frutos (frutos rojos) | Karışık meyve kombinasyonunu anımsatan aroma |
| Caramel | Flavor associated with cooked sugars | Karamellisoidun sokerin, toffeinen aromi | Arôme associé au sucre cuit | Aromen, die mit verkochtem Zucker assoziiert werden | Sensazione aromatica associata con zuccheri cotti | Aroma asociado a azúcar caramelizada | Karamelize şekeri anımsatan aroma |
| Chemical | Flavor of chemicals (e.g. ethyl acetate, plastic, sulphur, spirits) | Kemikaalien aromi (esim. etyyliaetaatti, muovi, rikki, alkoholi) | Arôme de produits chimiques (e.g. acétate d'éthyle, plastique, soufre, spiritueux) | Geruch nach Chemikalien (z. B. Ethylacetat, Plastik, Schwefel, Spiritus) | Odore di chimico (es. acetato di etile, plastica, zolfo, alcol) | Aroma asociado a químicos (ej. acetato de etilo, plástico, sulfurado) | Kimyasal maddeleri anımsatan aroma (etil asetat, plastik, kükürt, alkollü içkiler vs.) |
| Citrus | Flavor associated with citrus fruit (e.g. lemon, orange, lime) | Sitruhedelmän aromi (esim. sitruuna, appelsiini, lime) | Arôme associé aux agrumes (ex. citron, orange, citron vert) | Aromen, die mit Zitrusfrüchten assoziiert werden (z. B. Zitrone, Orange, Limette) | Sensazione aromatica associata ad agrumi (es. limone, arancia, lime) | Aroma asociado a los cítricos (ej. limón, naranja, lima) | Narenciye türlerini anımsatan aroma (portakal, limon vs.) |
| Cloying | Associated with an unrefreshing, sickening flavor | Epätuore, ällöttävä aromi | Arôme associé à une odeur nauséabonde | Geruch, der übermäßig süßlich ist, in einem fast ekelregenden Ausmaß | Aroma associato con qualcosa di non fresco, odore nauseante | Aroma asociado a fruto no fresco/empalagoso | Taze olmayan, mide bulandırıcı bir aroma |
| Fermented | Flavor associated with fermented /rotting fruit or vegetable | Käyneen, pilaantuneen hedelmän tai vihanneksen aromi | Arômes associés à un fruit ou un légume fermenté/pourri | Aromastoffe, die mit fermentiertem/faulen Obst oder Gemüse assoziiert werden | Sensazione aromatica associata con frutta o verdura fermentata/marcia | Aroma asociado a la fermentación y la fruta podrida | Fermente/çürüyen meyve veya sebze anımsatan aroma |
| Floral | Associated with flavor of flowers | Kukkaan liittyvä makea aromi | Arôme associée à l'odeur des fleurs | Erinnert an den Geruch von Blumen | Sensazione aromatica associata ai fiori | Asociado a aroma de flores | Çiçek kokusunu anımsatan aroma |
| Fruity | Sweet, intense flavor associated with a combination of mixed fruit | Hedelmiin liittyvä makea aromi | Arôme doux et intense associé à un mélange de fruits | Süßliches, intensives Aroma in Verbindung mit einer Kombination aus gemischten Früchten | Intensa sensazione aromatica dolce associata al mix di frutta fresca | Aroma dulzón, intenso, asociado a una mezcla de frutos | Karışık meyve kombinasyonunu anımsatan tatlı, yoğun aroma |

Table 4. Cont.

| Attributes Appearance | ENGLISH Description Appearance | FINNISH Kuvaus Ulkonäkö | FRENCH Description Apparence | GERMAN Beschreibung Aussehen | ITALIAN Descrizione Apparenza | SPANISH Descripción Apariencia | TURKISH Tanim Görünüm |
|-----------------------|---|--|--|---|--|---|---|
| Grassy | Refers to the flavor of green, grassy and leafy-like aromas | Vastaleikatun ruohon aromi | Arôme d'herbe fraîchement coupée | Aroma das Bezieht sich auf durch geschnittenes Gras | Sensazione aromatica, erba appena tagliata o foglie | Aroma asociado a la hierba verde, hoja | Yeşil, çimenli ve yaprak benzeri aromaları anımsatan aroma |
| Green | Associated with flavour of freshly cut green grass | Tuore tuoksu, esim. leikattu ruoho, raaka hedelmä, aromi | Arôme de fruits verts / pas mûrs | Ein unreifes Aroma das unreife, grüne Früchte. | Sensazione aromatica associata ai frutti immaturi | Un aroma a inmaduro, característico , la fruta verde inmadura | Taze kesilmiş çimeni anımsatan aroma |
| Green tomato | Flavor associated with unripe tomato (green tomato) | Kypsymättömään tomaattiin liittyvä aromi | Arôme associé à la tomate verte (non mure | Aromen, die an unreife Tomaten erinnern (grüne Tomaten) | Sensazione aromatic associate al pomodoro non maturo (verde) | Aromáticos asociados al tomate inmaduro (tomate verde) | Olgunlaşmamış domates (yeşil domates) ile ilişkili aroma |
| Minty | Refers to the minty flavor and cooling sensations | Minttuun tai viilentävään tunteeseen viittaava aromi | Arôme de menthe qui donne une sensation rafraichissante | Bezieht sich auf die minzigen und kühlenden Aromen | Sensazione riferita ad aroma di menta, una sensazione di fresco | Aroma mentolado y de sensaciones refrescantes | Ferahlama hissi veren nane benzeri aroma |
| Nutty | Flavor associated with nuts | Pähkinän aromi | Arôme associé à la fruit sec | Aroma, das an Nüsse erinnert | Sensazione aromatica associata con la frutta secca | Aroma asociado a las nueces, las avellanas, las almendras y en general a los frutos secos. | kuru meyve aroma |
| Raspberry | Flavor of fresh raspberries | Tuoreen vadelman aromi | Arôme de framboises | Aroma frischer Himbeeren | Sensazione aromatica associata al lampone | Aroma asociado de las frambuesas frescas | Taze ahududu tadı ve aromasının |
| Sweet | A sweet impression such as cotton candy, honey, vanilla or sweet fruity candy (not berry) that may appear in the aroma or aromatics | Makea, vaniljainen, makeisiin, makeaan tuoksuun liittyvä aromi | Arôme donnent une impression sucrée comme de la barbe à papa, du caramel, de la vanille ou des bonbons fruités | Ein süßlicher Geruch Geschmack wie Zuckerwatte, Karamell, Vanille oder süße Fruchtbonbons (keine Beeren), der im Aroma oder in der Duftnote auftreten kann. | Sensazione aromatica associata con il dolce come zucchero filato, caramello, vaniglia | Aroma asociado al algodón dulce, caramelo, vainilla, o caramelos afrutados (no a bayas o pequeños frutos) | Pamuklu şeker, karamel, vanilya gibi tatlılıkla (üzümü meyveler dışında) ilişkilendirilen aroma |
| Tropical fruit | Flavor associated to tropical fruits such as pineapple, mango, guava, passion fruit | Trooppisten hedelmien aromi (esim. ananas, mango, guava, passionhedelmä) | Arôme associé aux fruits tropicaux tels que l'ananas, mangue, goyave, fruit de la passion | Aroma verbunden mit tropischen Früchten wie Ananas, Mango, Guave, Passionsfrucht | Aroma associate con frutti tropicali come ananas, mango, guaiava e frutto della passione | Aroma asociado a frutas tropicales como piña, mango, guayaba, maracuyá | Ananas, çarkifelek meyvesi, mango, guava gibi tropik meyvelerle ilişkili aroma |
| Woody | Flavor associated with greenwood or stems | Tuoreen puun, oksien aromi | Aromatique associé au bois vert ou aux tiges | Aromen, die mit Grünholz oder Stengeln assoziiert werden | Aroma associato con legno verde | Aroma asociado a maderas verdes o ramas | Yeşil ağaç veya saplarını anımsatan aroma |
| Watery | Associated with watery taste, tame, tasteless | Vetinen, laimea maku, mauton | Associé au goût aqueux, approuvoisé, insipide | Assoziiert mit wässrig , mild | Flavour associato con un gusto acquoso, senza sapore | Asociado con sabor acuoso, soso, insípido | Sulu, yavan ve tatsız bir lezzet |
| Taste | Taste | Perusmaku | goût | Geschmack | Gusto | Sabor | Tat |
| Acid | Related to the basic taste acid | Happamuuden aiheuttama maku | goût associé à l'acidité | Bezogen auf den Grundgeschmack Sauer | Gusto associato con composti acidi | Sabor ácido | Ekşi tat |
| Bitter | Related to the basic taste bitter | Karvasaineiden aiheuttama maku | goût associé à la stimulation de la langue par un composé amer | Bezogen auf den Grundgeschmack Bitter | Gusto associato con la stimolazione della lingua con composti amari | Sabor amargo | Acı tat |
| Sweet | Related to the basic taste sweet | Sokerien tai makeutusaineiden aiheuttama maku | goût associé à la stimulation de la langue par le sucre ou un édulcorant | Bezogen auf den Grundgeschmack Süß | Gusto associato con la stimolazione della lingua con zucchero o dolcificanti | Sabor dulce o azucarado | Tatlı tat |

Table 4. Cont.

| Attributes Appearance | ENGLISH Description Appearance | FINNISH Kuvaus Ulkonäkö | FRENCH Description Apparence | GERMAN Beschreibung Aussehen | ITALIAN Descrizione Apparenza | SPANISH Descripción Apariencia | TURKISH Tanim Görünüm |
|-----------------------|--|--|---|---|---|---|--|
| Texture/mouthfeel | Texture/Mouthfeel | Rakenne/Suutuntuma | Texture/Texture En Bouche | Textur/Mundgefühl | Sensazione in bocca | Textura | Doku/Ağız hissi |
| Astringent | Feeling in the mouth characterized by drying; associated with the presence of tannins | Kutistava, kurova tai kuivaava tunne suussa; tanniinien aiheuttama | Sensation complexe résultant de la contraction des muqueuses de la bouche, similaire à la sensation de sécheresse, associée aux tanins. | Gefühl im Mund, das durch Austrocknung gekennzeichnet ist; wird mit dem Vorhandensein von Tanninen in Verbindung gebracht | Sensazione in bocca di secchezza, associate con la presenza di tannini | Sensación compleja que resulta de la contracción de las mucosas de la boca, parecida a la sensación de sequedad, asociada a los taninos | Tanenlerin varlığından damakta hissedilen kuruma hissi |
| Fibrous | The degree to which fibers are perceived throughout mastication | Kuitujen aistimisen aste pureskeltaessa | Degré de perception des fibres pendant la mastication | Grad der Wahrnehmung von Fasern während des Kauens | Grado con cui sono percepite fibre durante la masticazione | Grado de percepción de fibras durante la masticación | Çiğneme boyunca liflerin algılanma derecesi |
| Firm | Force required to bring teeth together during the mastication | Purentaan tarvittava voima | Force nécessaire pour rapprocher les dents pendant la mastication. | Kraft, die erforderlich ist, um die Zähne während des Kauens zusammenzubekommen | Forza necessaria per la masticazione | Fuerza necesaria para unir los dientes durante la masticación | Çiğneme sırasında dişleri bir araya getirmek için gereken kuvvet |
| Metallic | Metallic perception in the mouth | Metallinen aistimus suussa | sensation métallique en bouche | Metallische Wahrnehmung im Mund | Percezione metallica in bocca | Sensación metálica en boca | Düşükten yükseğe meyvenin sululuk derecesi |
| Juicy | The degree of juice presence | Mehupitoisuus | Quantité de jus dans le fruit | Grad des Vorhandenseins von Saft (Saftigkeit) | Grado di presenza di succo | Cantidad de jugo en el fruto | Damaktaki metalik algı |
| Seedy | Seeds percived during mastication | Pureskeltaessa havaittavat siemenet | Degré de présence des graines pendant la mastication. | Während des Kauens wahrgenommene Samen | Semi percepiti durante la masticazione | Grado de percepción de las semillas durante la masticación | Çiğneme sırasında algılanan çekirdekler |
| Metadescriptor | Metadescriptor | Yleisvaaja | Metadescriptor | Metadeskriptor | Metadescrittore | Metadescriptor | Meta tanımlayıcı |
| Freshness | Meta-descriptor, satisfaction of mix features (appearance, textural, aromatic and tasting) | Yleiskuvaaja eri tekijöiden yhteisvaikutus huomioiden (ulkonäkö, aromi, rakenne, maku) | Méta-descripteur, satisfaction de la combinaison de toutes les caractéristiques (aspect, texture, arôme et goût) | Meta-Deskriptor, Zufriedenheit mit der Kombination aller Merkmale (Aussehen, Textur, Aroma und Geschmack) | Metadescrittore, soddisfazione di un mix di caratteristiche (apparenza, texture, aroma gusto) | Metadescriptor, satisfacción por la combinación de varias características (aparencia, textura, aroma y gusto) | Meta-tanımlayıcı, karışım özelliklerinin tatmini (görünüm, dokusal, aromatik ve tat) |

Table 5. Frequency counts of the sensory descriptors of blueberry samples. Attributes marked by *** belong to the third tertile, ** belongs to the second tertile, * belongs to the first tertile (peculiar traits). “-” indicates non-used attributes.

| Attribute Modality | Attribute | AtlasBlue | Cultivar Rebel | Ventura | Counts | Overall Frequency |
|--------------------|----------------------|-----------|----------------|---------|--------|-------------------|
| Flavor | Acid *** | 17 | 17 | 25 | 59 | 61.5 |
| | Berry ** | 15 | 15 | 18 | 48 | 50.0 |
| | Blueberry *** | 28 | 26 | 30 | 84 | 87.5 |
| | Citrus - | 7 | 7 | 10 | 24 | 25.0 |
| | Earthy/musty * | 10 | 15 | 5 | 30 | 31.3 |
| | Fermented * | 8 | 13 | 8 | 29 | 30.2 |
| | Floral ** | 23 | 18 | 15 | 56 | 58.3 |
| | Fruity ** | 16 | 18 | 17 | 51 | 53.1 |
| | Grassy * | 11 | 14 | 10 | 35 | 36.5 |
| | Green ** | 17 | 16 | 11 | 44 | 45.8 |
| | Minty - | 8 | 6 | 8 | 22 | 22.9 |
| | Overripe fruit * | 7 | 18 | 6 | 31 | 32.3 |
| | Pungent * | 10 | 9 | 13 | 32 | 33.3 |
| | Spicy - | 6 | 7 | 4 | 17 | 17.7 |
| | Strawberry - | 5 | 4 | 7 | 16 | 16.7 |
| Sweet *** | 25 | 21 | 19 | 65 | 67.7 | |
| Watery - | 0 | 0 | 0 | 0 | 0.0 | |
| Taste | Acid *** | 15 | 20 | 30 | 65 | 67.7 |
| | Bitter - | 8 | 8 | 6 | 22 | 22.9 |
| | Sweet *** | 31 | 25 | 27 | 83 | 86.5 |
| Mouthfeel | Astringent ** | 13 | 17 | 17 | 47 | 49.0 |
| | Fibrous ** | 15 | 16 | 14 | 45 | 46.9 |
| | Firm ** | 20 | 18 | 20 | 58 | 60.4 |
| | Metallic - | 4 | 5 | 5 | 14 | 14.6 |
| | Juicy *** | 28 | 25 | 30 | 83 | 86.5 |
| | Seedy - | 0 | 0 | 0 | 0 | 0.0 |
| | Skin persistence *** | 29 | 26 | 22 | 77 | 80.2 |
| Throat burn * | 9 | 6 | 12 | 27 | 28.1 | |
| Metadescriptor | Freshness *** | 24 | 23 | 26 | 73 | 76.0 |
| | Overall | 409 | 413 | 415 | 1237 | 50.8 |

Analyzing RATA data through the Venn diagram showed that several high- and medium-frequency attributes were shared by the three blueberry cultivars, while peculiar traits discriminated them (Figure 2). Fifteen attributes were shared by all the cultivars, and three attributes (overripe fruit, fermented, and earthy/musty) were absent in AtlasBlue and Ventura. Two attributes (throat burn and pungent), were present in Ventura only, and one attribute (grassy), was common to AtlasBlue and Rebel.

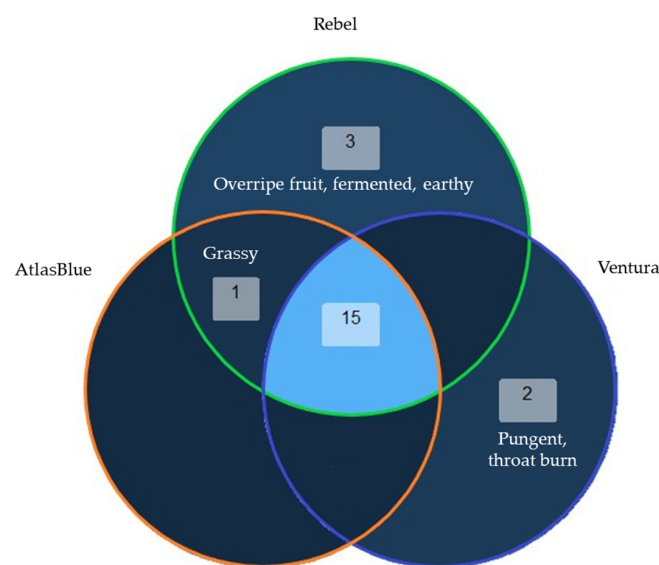


Figure 2. Venn diagram based on the attributes chosen by at least 34% of the panelists to describe blueberry cultivars. Numbers inside the diagram represent the number of terms selected by the panelists.

3.2.2. Blueberry Cultivar Profiles

The three blueberry cultivars differed in six of the “high frequency” attributes with Ventura recording the highest intensity of juiciness, acidity, freshness and blueberry flavor, while AtlasBlue prevailed for sweetness and sweet flavor (Figure 3). “Medium frequency” attributes also contributed to define the cultivar profiles; Rebel recorded the lowest firmness and the highest grassy flavor, Ventura was the least fibrous, and AtlasBlue registered the most intense floral flavor. Finally, peculiar traits, having generally a low intensity, contributed to cultivar discrimination; Ventura showed the highest throat burn and pungency, and Rebel showed the highest fermented, earthy/musty, and overripe fruit flavors.

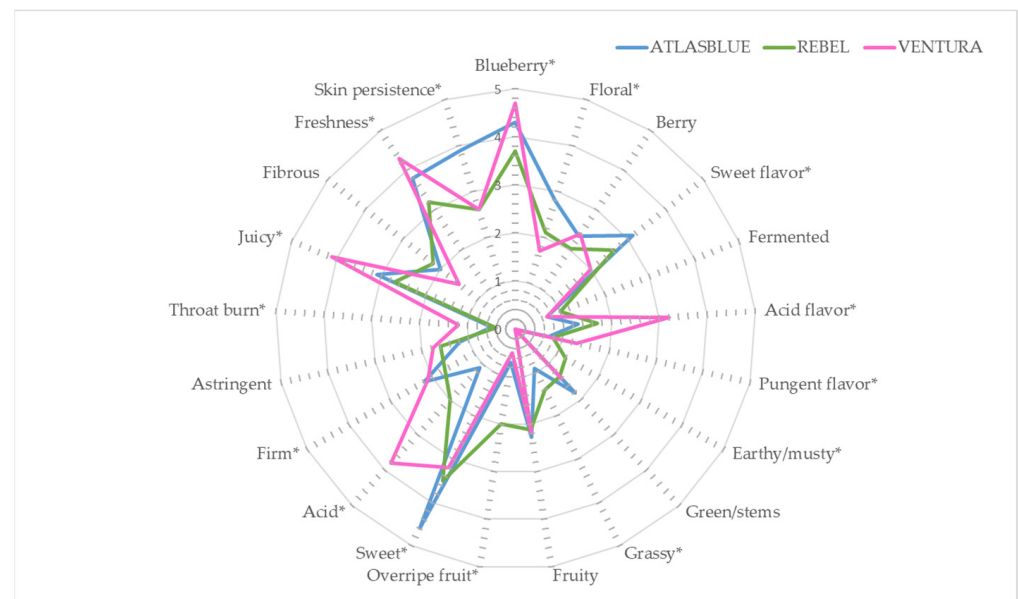


Figure 3. Spider plot of blueberry RATA intensity scores by cultivars on a 10-point scale (0–9). Significant differences ($p < 0.05$) between cultivars are marked by *.

Repeatability did not have any significant effect on replicate.

3.2.3. Raspberry Lexicon Sorting through RATA

Six of the 29 raspberry attributes were in the third tertile (high frequency) of panel citation: raspberry flavor, sweet taste, acid taste, astringent, juicy, and seedy. Eight additional attributes were used by a minimum of 34% of the panelists: freshness, firm, fruity, cloying, green, floral flavors, fibrous, and grassy, and belonged to the second tertile. Of the remaining attributes, two (bitter and chemical flavors) overcome this threshold at least in one cultivar. The attributes metallic, woody, watery and caramel flavors had a low frequency (peculiar traits), and the attributes berry, citrus, fermented, green tomato, minty, nutty, sweet and tropical fruit flavors were not used by the panelists to describe the berries (Table 6).

The Venn diagram of the raspberry RATA data showed that 14 “medium and high-frequency” attributes were common to the three cultivars. Only two cultivars were discriminated by peculiar traits (Lagorai Plus and Adelita) (Figure 4). Two attributes, chemical and bitter, were absent in Lagorai Plus and Dafne, and one attribute, cloying, was common to Lagorai Plus and Adelita. The attribute fibrous was present in Lagorai Plus only.

Table 6. Frequency counts of the sensory descriptors of raspberry samples. Attributes marked by *** belong to the third tertile, ** means belonging to the second tertile, * means belonging to the first tertile (peculiar traits). “-” indicates non-used attributes.

| Attribute Modality | Attribute | Lagorai Plus | Cultivar Dafne | Adelita | Counts | Overall Frequency |
|--------------------|------------------|--------------|----------------|---------|--------|-------------------|
| Flavor | Acid *** | 24 | 22 | 24 | 70 | 83.3 |
| | Berry - | 0 | 0 | 0 | 0 | 0.0 |
| | Caramel - | 3 | 5 | 5 | 13 | 15.5 |
| | Chemical * | 8 | 9 | 13 | 30 | 35.7 |
| | Citrus - | 0 | 0 | 0 | 0 | 0.0 |
| | Cloying ** | 12 | 6 | 18 | 36 | 42.9 |
| | Fermented - | 0 | 0 | 0 | 0 | 0.0 |
| | Floral ** | 12 | 15 | 13 | 40 | 47.6 |
| | Fruity ** | 12 | 16 | 16 | 44 | 52.4 |
| | Grassy ** | 11 | 11 | 10 | 32 | 38.1 |
| | Green ** | 13 | 11 | 13 | 37 | 44.0 |
| | Green tomato - | 0 | 0 | 0 | 0 | 0.0 |
| | Minty - | 0 | 0 | 0 | 0 | 0.0 |
| | Nutty - | 0 | 0 | 0 | 0 | 0.0 |
| | Raspberry *** | 21 | 25 | 22 | 68 | 81.0 |
| | Sweet | 0 | 0 | 0 | 0 | 0.0 |
| | Tropical fruit - | 0 | 0 | 0 | 0 | 0.0 |
| Watery - | 10 | 9 | 7 | 26 | 31.0 | |
| Woody - | 10 | 8 | 10 | 28 | 33.0 | |
| Taste | Acid *** | 26 | 27 | 26 | 79 | 94.0 |
| | Bitter * | 5 | 6 | 12 | 23 | 27.4 |
| | Sweet *** | 19 | 26 | 22 | 67 | 79.8 |
| Mouthfeel | Astringent *** | 21 | 19 | 20 | 60 | 71.4 |
| | Fibrous ** | 11 | 9 | 9 | 29 | 34.5 |
| | Firm ** | 20 | 17 | 18 | 55 | 65.5 |
| | Metallic - | 8 | 6 | 8 | 22 | 26.2 |
| | Juicy *** | 24 | 28 | 25 | 77 | 91.7 |
| | Seedy *** | 25 | 25 | 26 | 76 | 90.5 |
| Metadescriptor | Freshness ** | 15 | 14 | 15 | 44 | 52.4 |
| | Overall | 323 | 331 | 347 | 1001 | 1191.7 |

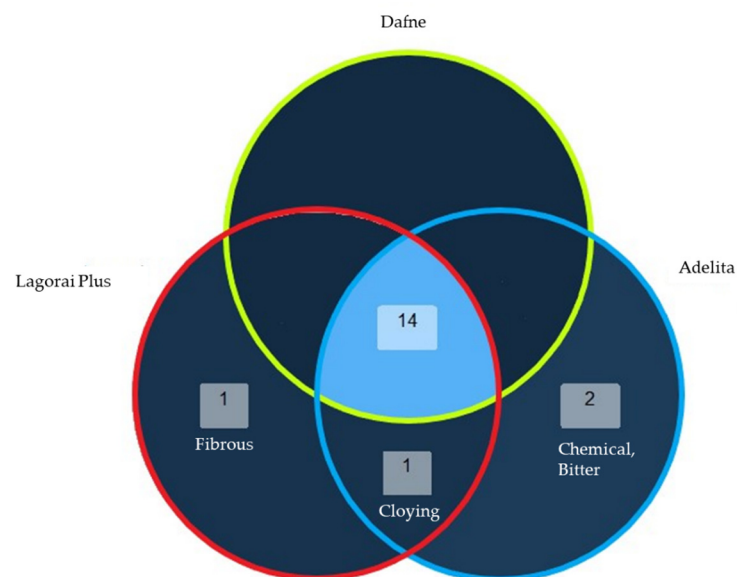


Figure 4. Venn diagram based on the attributes chosen by at least 34% of the panelists to describe raspberry cultivars. Numbers inside the diagram represent the number of terms selected by the panelists for each cultivar.

3.2.4. Raspberry Cultivar Profiles

The three raspberry cultivars tested were different for four of the “high frequency” attributes; Dafne and Adelita showed the highest intensity of raspberry flavor, Dafne also showed the highest juiciness and sweetness, while Lagorai Plus was the most acid (Figure 5). “Medium frequency” attributes also contributed to define cultivar profiles; Lagorai Plus

showed the highest firmness and fibrousness, Dafne was mainly fruity, and Adelita was mainly cloying and grassy. Among peculiar traits showing generally low intensity, Adelita expressed the highest bitter and chemical flavors.

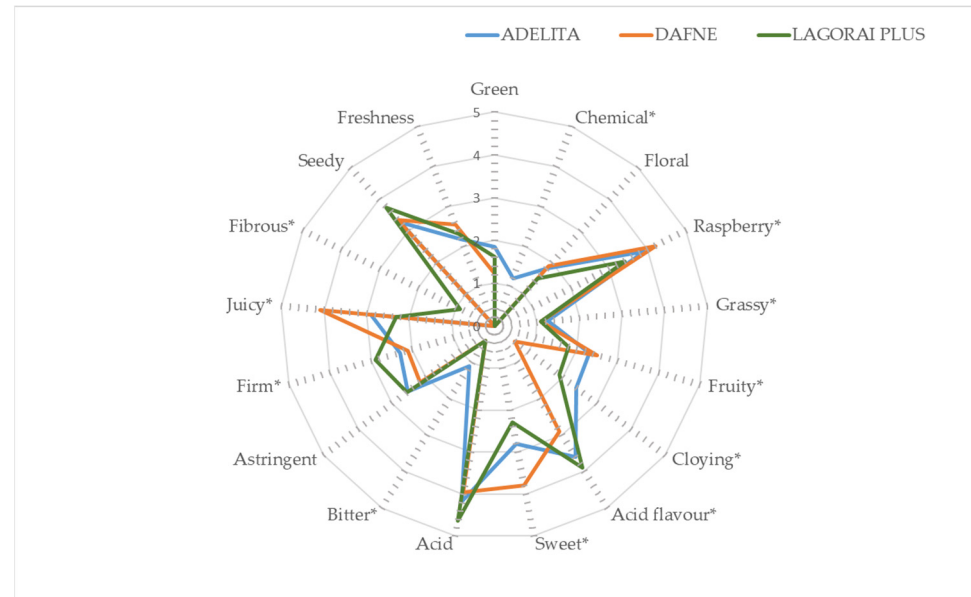


Figure 5. Spider plot of raspberry RATA intensity scores by cultivars on a 10-point scale (0–9). Significant differences ($p < 0.05$) between cultivars are marked by *.

Repeatability did not have any significant effect on replicate.

4. Discussion

4.1. Berries Lexicon Development

This study led to the identification of 29 sensory descriptors perceived during eating (basic tastes, texture, flavors) potentially present in blueberry, and the same number in raspberry, evidencing an expected high range of sensory stimuli provided by the berries. As suggested by Suwonsichon [4], lexicon creators have to clearly illustrate each chosen term to panelists, referring to previous experiences, and/or providing standard references to support panelists' term/sensation association, to validate the effectiveness and the exhaustiveness of the terms list.

4.2. Basic Tastes

In this study, the lexicon was validated by panelists through RATA, as applied on three blueberry and three raspberry cultivars selected for providing a wide range of product variability. Basic tastes such as sweet and acid are clearly perceived in most fruit including berries, due to the relevant presence of sugars (and polyalcohols) and organic acids [30]; also in this study, they were cited at high frequency both in blueberry and raspberry. Bitter recorded lower frequencies, being not typical of these fruits [15,28]. However, as it affects consumers' liking [28] it is worth assessing, even if only slightly perceived. Indeed, the bitter perception has a recognized genetic base, with about one third of consumers (supertasters), particularly sensitive to bitterness [31]. In our study, bitter taste was highlighted by more than one third of assessors only in the raspberry cultivar "Lagorai".

4.3. Flavors

Berries are particularly rich in odor active compounds, determining odor and flavors. For raspberry, the most impacting compound, responsible for the typical raspberry-like odor, is 4-(4-Hydroxyphenyl) butan-2-one, the "raspberry ketone" [26,32]. While the blueberry flavor is a mix of odor compounds not corresponding to a single odor sensation,

among them, the ones affecting the overall liking were reported to be 1-hexanol and 2-undecanone, responsible, respectively, for fruity/sweet/green, and fruity/floral sensations [18]. However, in this study, both blueberry and raspberry flavors were clearly recognized by judges who cited them highly (over 80% citation frequency). Additional cited flavors in blueberry were acid and sweet, and at low frequencies, floral, fruity, berry and green, which are also responsible for blueberry flavor. Additional cited flavor notes in raspberry were fruity, cloying, green, floral and grassy.

4.4. Mouthfeel

Among texture descriptors, juiciness was highly cited for both berries, indeed it has been considered a positive trait often related to liking [20]. Firmness was also frequently cited but at a low intensity due to the general features of these berries. Fibrousness was also cited but among the low-frequency attributes. Other texture attributes were berry type-specific: skin persistence in blueberry, seedy in raspberry. Astringency, another key attribute of fruit, related to the concentration of substances such as polyphenols [33], received medium frequency citations in blueberry and high in raspberry. Freshness, an important metadescriptor of sensations related to just-harvested fruits [17,29] was cited at high frequency in blueberry, and medium frequency in raspberry, suggesting the perishable nature of raspberry.

4.5. RATA Analysis

RATA was confirmed to be a quick and valuable alternative to the complicated traditional sensory lexicon development, as highlighted by Leone et al. [10]. Indeed, RATA has been considered a tool to produce data in line with consumer perceptions with a short time frame for data acquisition [34]. Moreover, the advantage of RATA resides in the ease of lexicon development since the terms selected are directly applied and rated [35]. Our descriptive and comparative test on blueberry and raspberry cultivars confirmed the selected lexicon efficiency through sample discrimination highlighted by attributes' intensities. Notably, not only high-/medium-frequency terms help discriminate between cultivars, but also peculiar traits, underlining their important role in describing food products. Thus, RATA was useful, especially in correctly identifying discriminative, peculiar traits of the product analyzed.

4.6. Pros and Goals

The main novelty of this research is the development of a comprehensive multilingual lexicon for raspberries and blueberries, the sensorial quality of which has been little investigated so far. Moreover, it provides a fundamental sensory tool not only for international research studies involving different partners and countries but also for breeders and the food industry to assess the potential of new varieties in the fresh fruit market, necessary in modern breeding programs aimed at improving fruit sensorial and nutritional quality [36]. Lexicon development should be seen as a necessary starting point, from which other sensory studies can evolve using well-documented terms directly or adding/adapting new terms to each individual work [37]. The lexicon developed in the present study to describe the sensory properties of fresh raspberry and blueberry will be applied in further tests in the frame of the BreedingValue project in different European countries [11], both to assess the translation relevance and to provide the opportunity for further lexicon integration.

5. Conclusions

The seven-language lexicon developed in this study can contribute to systematize blueberry and raspberry sensory evaluation at an international level. A reference sensory lexicon is useful to ease producer-consumer interaction; moreover, international markets and scientific collaborations need a multilingual lexicon to share a common meaning of each term. This research provides a comprehensive list of terms for blueberry and raspberry sensory evaluation in some of the world's most spoken languages, such as English, Spanish

and French, and in additional languages spoken in relevant berry production countries, such as Germany, Italy, Finland, and Turkey. The proposed lexicon can be used as a tool for planning panel training and consumer tests, opening up further possibilities to enrich the lexicon based on additional attributes emerging from local experience, or evaluation of new genotypes. Indeed, the lexicon, developed in English and validated by an Italian expert panel, can be applied in other languages. The developing procedure presented in this study, which starts from English, is the “hub” connecting several “spokes”, i.e., the languages, and easily allows both integrating the list of sensory terms and add more languages. The international Breeding Value consortium collaboration led to the creation of this unique tool, setting the basis for a consistent sensory evaluation of blueberry and raspberry fruits.

Author Contributions: Conceptualization, N.L., E.S., M.C. (Marta Cianciabella) and S.P.; methodology, S.P., B.M. and S.K.; validation, M.C. (Medoro Chiara), M.C. (Marta Cianciabella), E.G. and S.P.; investigation, B.D., D.A.S., M.F., M.H., N.L., N.E.K., L.M., M.C. (Marta Cianciabella), S.M., K.O., S.O. (Saverio Orsucci), S.O. (Sonia Osorio), E.S., D.P., S.R., J.F.S.-S., G.S., C.S., B.U. and P.Z.; data curation, N.L., M.C. (Marta Cianciabella) and M.C. (Medoro Chiara) writing—original draft preparation, N.L., M.C. (Marta Cianciabella) and E.S.; writing—review and editing, M.C. (Marta Cianciabella), M.C. (Medoro Chiara), E.S., S.K., K.O., S.R., D.P. and N.E.K.; funding acquisition, B.M. and S.P. All authors have read and agreed to the published version of the manuscript.

Funding: This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 101000747.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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