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A Comparative Analysis of Plant-Based Milk Alternatives Part 1: Composition, Sensory, and Nutritional Value

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Abstract: Consumers are becoming increasingly interested in reducing the consumption of animal-based foods for health, sustainability, and ethical reasons. The food industry is developing products from plant-based ingredients that mimic animal-based foods' nutritional and sensory characteristics. In this study, the focus is on plant-based milk alternatives (PBMAs). A potential problem with plant-based diets is the deficiency of important micronutrients, such as vitamin B_{12}, B_2, and calcium. Therefore, an analysis of micronutrients in PBMAs was conducted to assess their nutritional value. The second main focus was on the sensory description of the PBMAs, done by a trained panel, and instrumental assessment to characterize the sensory attributes. Almond drinks met the daily micronutrient requirements the least, while soy drinks came closest to cow's milk in macro- and micronutrients. The experimentally determined electronic tongue and volatile compound results confirmed the sensory panel's evaluations and could therefore be used as a method for easy and effective assessments of PBMAs. The PBMAs evaluated in this study could not completely replace cow's milk's nutritional and sensory properties. They are products in their own product group and must be evaluated accordingly. Given the variety of products, consumers should experiment and make their decisions regarding the substitution of cow's milk.

Keywords: almond drinks; micronutrients; milk substitutes; non-dairy beverages; oat drinks; sensory evaluation; soy drinks

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1. Introduction

Worldwide dietary recommendations published on homepages and in reports and guidelines are based on established scientific evidence recommending a predominantly plant-based diet [1–5]. For the most part, it consists primarily of vegetables and fruits, complemented with whole grain products, adequate protein from plant and animal sources, and vegetable fats. Meat and meat products, as well as foods that are high in sugar, salt, and saturated fats, should be consumed only in moderate amounts. The increasing demand for a Western-style diet is exerting pressure on the global food supply. The high consumption of animal products, especially beef and milk, is one of the main reasons contributing to the negative impact of the modern diet on global and individual health [6,7]. Therefore, there is great interest in shifting to a more plant-based diet when it comes to, for example, environmentally friendly or balanced nutrition to support public health at all levels of society–personal, community, national, regional, global, and planetary health. Indeed, our food system in its current form contributes significantly to the climate crisis, resource depletion, and loss of intact ecosystems, especially through intensive livestock farming [8–10].

There is significant interest in the development of plant-based milk alternatives (PBMAs) to cow's milk. Consumers are looking for specific functions in these beverages that are part of their lifestyle and meet different needs. One of these important functional requirements for PBMAs is primarily to address health aspects such as the problems of cow's milk allergy, lactose intolerance, high caloric intake, and prevalence of hypercholesterolemia [11]. Concerning lactose, it should be noted that approximately 75% of the world's adult population cannot digest this carbohydrate or can only partially digest it [12]. Ethnic origin influences the frequency of lactose intolerance. In Europe, people in Great Britain, The Netherlands, and Scandinavia have a low level of intolerance (1–15%), while people in Asian countries, such as China, Thailand, and Southeast Asia, have very high intolerance (95–98%) [12].

The consumption of PBMAs has increased in Europe from 2018 to 2020 [13] because they contain no lactose and no milk protein, are cholesterol-free, contain no trans-fatty acids, and are low in calories, making them suitable not only for special populations but appealing to a broader population. In addition to the health aspect, a recent study [14] conducted in an online survey of young adults from Germany shows that awareness of a climate-conscious diet is growing. The same authors concluded that the trend of vegetarian, vegan, and flexitarian diets is increasing, and plant-based alternative products are popular among the respondents, especially PBMAs are well-perceived. Another online survey of young adults grouped as "Future-Oriented Climate Protectors" is noticeably open to plant-based alternatives [15]. For example, they appreciate that many more alternative products are available and would like to see an even wider range in supermarkets. Another current study by Turnwald et al. [16] analyzed data from social media personalities with high followings who post nutrition messages and found that posts with "healthier" foods were associated with fewer "likes" and comments, suggesting lower user approval. The authors of this study suggest that the representation of the consumption of "unhealthy" foods and beverages in social media can lead to a sociocultural problem, especially in the dietary habits of children and adolescents. Considering data on PBMAs from an economic point of view, based on global and European surveys, these show that these products have gained acceptance in the market and among consumers. The global market development for PBMAs is anticipated to grow at a compound annual growth rate (CAGR), a percentage indicating how much the value under consideration is increasing on average per year, of 12.5% from 2021 to 2028, and is expected to reach a value of US $20.5 billion [17]. According to a study by the Smart Protein Project [13], the market for PBMAs in Europe is growing both in sales value in euros and sales volume in liters. For example, data for Austria show that PBMAs had the highest-value sales (€37 million) and the highest volume sales (19 million liters) compared to those of other plant-based products. The segment of plant-based beverages is dominated by oats, almonds, and soy, which are currently the main raw materials and are dominant but may vary slightly in their ranking depending on the country [16].

The general classification of PBMAs according to the raw materials (legumes, nuts, cereals, pseudocereals, oilseeds) into five categories is currently applied in the literature [11,18–21]. PBMAs are liquids extracted by crushing plant material in water and designed by homogenization to be quite similar to cow's milk in appearance, mouthfeel, taste, and shelf life so that they can be used for similar applications [11,18,19]. Since the sensory properties play a crucial role in the consumption of plant-based beverages, undesirable off-flavors should be reduced. Off-flavors often described include a beany taste in soy-based products, a high degree of bitterness, and impaired textural quality, for example, due to a high starch content [11,22]. Furthermore, off-flavors can be caused by volatile compounds formed during the oxidation of lipids, such as hexanal, hexanol, and pentanal [22,23].

According to the NOVA classification (which is not an acronym), a categorization of foods and beverages based on degrees of processing, PBMAs are classified in NOVA group 3 (processed foods) or 4 (ultra-processed foods, UPFs), whereas fresh and pasteurized cow's milk belongs to natural and minimally processed foods (group 1) [24,25]. UPFs are classified as follows: synthetic ingredients are added to the usual high-tech, industrial processes such as additives, flavorings, as well as vitamins and minerals. Although the term "milk" for plant-based alternatives is controversial in many countries, as in Europe, the term for cow's milk is protected by legislation [26]. PBMAs are often marketed in German food retailing by naming the raw material base and adding "drink". In the United States, the Food and Drug Administration recently investigated whether beverage manufacturers of PBMAs may use the term "milk", and guidance on labeling is expected in 2022 [27].

In this study, PBMAs were analyzed, and their composition was discussed from a nutritional and sensory perspective. The main objective was to investigate the micronutrients of conventional PBMAs from different raw material sources in order to compare their nutritional values with that of cow's milk and assess whether there are health benefits. In addition, a complete overview of the macronutrients ("Big 7") was given to gain a better overview of the PBMAs related to their feedstock and to be able to benchmark these products against cow's milk. For the comprehensive sensory evaluation of PBMAs, qualitative descriptive panel work and instrumental sensory data were used in this paper.

2. Materials and Methods

2.1. Plant-Based Milk Alternative Samples and Data from Databases

Fifteen commercially available PBMAs were selected for the study, five of each of the three raw materials: almond, oat, and soy (Table 1). They were purchased in local grocery stores and online. For each product, samples with the same best before dates were used both in the sensory tastings and the analytical procedures to ensure the product itself was of the same batch. For the sensory evaluation and the analysis of volatile compounds and vitamins, fresh samples were used. For the assessments with the electronic tongue (e-tongue) and mineral analysis, freeze-dried material (freeze-dryer, EPSILON 2-40, Christ, Osterode am Harz, Germany) was used, which had previously been ground with a coffee grinder (KSW 3307, Clatronic International, Kempen, Germany) and stored at +4 °C until analysis. For comparison between the analyzed data and existing literature values of PBMAs and cow's milk, data were collected from the following four national nutrition databases: Food Standards Australia New Zealand, AUSNUT [28]; Fineli, the Nutrition Unit of the National Institute for Health and Welfare in Finland [29]; the US Department of Agriculture (USDA) FoodData Central Data, Food and Nutrient Database for Dietary Studies 2017–2018 [30]; and the Max Rubner-Institut, Federal Research Institute of Nutrition and Food, Bundeslebensmittelschlüssel (BLS) Version 3.02 [31].

2.2. Nutri-Score

The nutritional evaluation of PBMAs was performed according to the front-of-pack labeling rating system accepted and voluntarily applied in Germany since 2020 [32]. The Nutri-Score classifies foods into five categories according to nutritional quality (from category A, indicating higher nutritional quality, to category E, indicating low nutritional quality). These categories are additionally highlighted with a five-color traffic light labeling (from A being green to E being red). According to the current version of the Santé Publique France brand statutes, plant-based alternative beverages are treated as cow's milk, thus, the calculation of the Nutri-Score score is not according to beverages but is based on the calculation for solid products [33]. Nutrients were evaluated using the Nutri-Score system on a scale from −15 points (A) to +40 points (E) by the nutrient content per 100 g. Positive points (0–10) are determined for energy, total sugars, saturated fatty acids, and sodium, and negative points (0–5) are granted for fruits, vegetables, legumes, nuts and rapeseed, walnut and olive oils, dietary fiber, and proteins [33].

Table 1. Mean values of nutritional composition in g/100 g, energy in kcal/100 g, and Nutri-Score of tested plant-based milk alternatives and data from food databases [#].

Abbreviation [$]	Supplements	Raw Material (%)		Energy	Fat	SFA	Carbohydrate	Sugar	Fiber	Protein	Salt	Nutri-Score
JA	Z	2.0	Almond	14	1.2	0.1	0.1	0.0	0.4	0.4	0.12	B
AA	W,X,Y,Z	2.3	Almond	13	1.1	0.1	0.0	0.0	0.3	0.4	0.14	B
ALA *		7.0	Almond	36	3.3	0.3	0.5	0.5	0.7	1.1	0.14	B
RA *		3.5	Almond	22	2	0.2	0.0	0.0	0.4 [##]	0.9	0.12	B
ABA **	Z	2.5	Almond	24	1.2	0.1	2.6	2.5	0.3	0.5	0.08	B
OO	W,X,Y^1,Z	10.0	Oat	46	1.5	0.2	6.7	4.1	0.8	1.0	0.10	B
AO	W,X,Y,Z	9.8	Oat	44	1.5	0.1	6.8	3.3	1.4	0.3	0.09	A
KO *		11.3	Oat	44	1.1	0.2	7.6	4.5	0.6	0.7	0.10	B
BO *		11.0	Oat	46	1.4	0.2	7.6	5.2	0.9 [##]	0.7	0.13	B
ABO **		12.0	Oat	47	1.3	0.5	8.1	3.9	0.8	0.3	0.09	B
JS	X,Y,Z	7.1	Soy	38	1.7	0.2	2.5	2.4	0.5	3.0	0.09	A
AS	W,X,Y,Z	5.6	Soy	28	1.2	0.2	1.7	1.5	0.9	2.1	0.11	A
ES *		9.4	Soy	53	2.6	0.4	2.9	2.7	0.7 [##]	4.1	0.15	A
BS *		11.0	Soy	28	1.5	0.3	0.9	0.7	0.7 [##]	2.6	0.08	A
ABS **	W,X,Y,Z	8.7	Soy	42	1.9	0.3	2.7	2.5	0.6	3.3	0.10	A
Almond drink, Database (mean, n = 6)				24.0	1.39	0.07	2.26	1.89	0.27	0.57	0.15	B
Oat drink, Database (mean, n = 11)				51.7	1.39	0.17	7.86	2.83	1.27	1.24	0.09	A
Soy drink, Database (mean, n = 38)				44.0	1.69	0.28	3.62	2.02	0.83	3.15	0.10	A
Cow's milk, Database (mean, n = 55)				53.1	2.14	1.41	5.06	4.99	0.0	3.37	0.11	B

Note: nutritional properties defined on the packaging of the products; [$] description of the abbreviations: the first letter stands for the product name, the last letter stands for the raw material; A = almond, O = oat, S = soy, with three letters the, letter B stands for barista-style; [#] calculated mean values from AUSNUT, Fineli, USDA, BLS databases; [##] Nutri-Score calculated, for missing values calculation means; * organic; ** barista-style; SFA = saturated fatty acids; W = 0.21 mg vitamin B_2, X = 0.38 µg vitamin B_{12}, Y = 0.75 µg vitamin D, Y^1 = 1.1 µg vitamin D, Z = 120 mg calcium.

2.3. Micronutrient Analysis—Vitamins and Minerals

Finely ground, freeze-dried material was used for mineral analyses and stored at +4 °C until analysis. Mineral concentrations were determined using an adapted method of Koch et al. [34]. Approximately 100 mg of each sample was digested in 4 mL of 65% (*v*/*v*) nitric acid and 2 mL of 30% (*v*/*v*) hydrogen peroxide for 75 min at 200 °C and 40 bar in a microwave oven (Ethos 660; MWT AG, Heerbrugg, Switzerland). The samples were then made up to 25 mL with distilled water. Mineral concentrations were measured by inductively coupled plasma optical emission spectrometry (Vista-PRO CCD Simultaneous ICP-OES; Varian Inc., Palo Alto, CA, USA). For the vitamin analyses, refrigerated 250 mL of fresh sample material was sent to the bilacon food laboratory (bilacon GmbH, Berlin, Germany, Department of Instrumental Analysis). The lab services performed the analytics according to standardized and accredited procedures of the multimethod to determine water- and fat-soluble vitamins in food by LC-MS/MS (Method: PV-SA-158 and 159, 2019-02).

2.4. Sensory Evaluation

All training and evaluation sessions took place in the sensory lab of the Georg-August-University Goettingen, Germany, which complies with the international standard ISO 8589 [35]. Due to the COVID-19 pandemic (SARS-CoV-2) in 2020, a special hygiene concept had been developed, and the number of panelists had to be reduced to 8 (6 female/2 male). The panel met twice a week for a maximum of 120 min, and during the sessions, each panelist sat isolated in individual booths in daylight conditions. According to ISO 8586 guidelines [36], the panelists were selected and declared their agreement before participation. Training under DIN 10969 standards [37] took place to obtain significant data because descriptive analysis was used for the qualitative description of the samples and the quantification of the intensities and the degree of the sensory perceptions [38]. According to Lawless and Heymann [39], descriptive sensory analyses were subject to three main steps, which were also relevant for this work: the determination of sensory attributes, the training of panelists, and the sample characterization. The panel leader was the moderator for the panel to structure and guide the sessions. The first step was to find attributes, which were developed to describe the plant-based alternative products in appearance (_A), odor (_O), taste (_T), and texture (_TX). In total, 23 attributes were defined for all PBMAs (Table 2). The same evaluation form was used for all sensory sessions to ensure comparability of the results. The panel leader screened vocabulary for the attributes found through research to save time during training. The assessors generated the final list of descriptors through consensus. During the training, samples from other food and the sample set were served to demonstrate the common vocabulary and the meaning of each food product attribute [40]. The panelists decided on the references, the definitions, and the order of rating in consensus. In the training sessions, the assessors learned to assign each sample to the attribute and rate it on an unstructured scale with the endpoints 0% (not perceptible) to 100% (strongly perceptible) in relation to the reference. The training focused on the differentiation between samples, the consensus among panelists regarding samples, and the ability to repeat the products' evaluation. Sample preparation for the sensory evaluation of PBMAs was performed as follows: The samples were stored at 7 °C and brought to room temperature one hour before the start of the tasting, which was 20 ± 2 °C, before being presented to the panelists. The PBMAs were shaken vigorously by hand in their packaging to ensure that a homogeneous liquid was obtained. The odorless and transparent sample cups were always filled with 20 mL of the product and labeled with a three-digit random code. For data collection, the sample set was rated duplicated by each panelist in a randomized order and blinded by three-digit codes. After evaluating each sample, the panelists were invited to neutralize their sense of taste with water and white bread as well as coffee beans to neutralize their sense of smell, and then waited 2 min before beginning to evaluate the next sample. Data recording and analysis were performed with the software EyeQuestion® (Version 4.11.57, EyeQuestion®, Elst, The Netherlands).

Table 2. Sensory attributes, scales, reference products and definitions, and the assessment of the attributes used to evaluate plant-based milk alternatives.

Attribute	Abbreviation	Scale (from–to)	Reference/Definition [1]	Assessment
			Appearance	
Consistency	Con_A	Liquid–Viscous	Water = 0, Whipping cream = 80	Standard daylight in the booths
Intensity	Int_A	White–Brownish	Sample hue	
			Odor	
Overall	Over_O	Not perceivable–Strongly perceivable	All perceptible odor	Sample odor, holding it 2 cm under the nose, and sniffing three times
Cereal	Cer_O		Damp mixture of oats, wheat, rye, barley, spelt (Kölln Multikorn-Flocken)	
Nutty	Nut_O		Shredded nut mixture of cashew, walnut, hazelnut, almond (Seeberger)	
Cardboard	Card_O		Soaking square of cardboard in water for 30 min	
Milk	Milk_O		Fresh cow's milk, fat content 3.5%	
Cooking	Cook_O		Whole milk heated to steaming and cook 10 min	
Vanilla	Van_O		Pure vanilla extract diluted with water in a ratio of 1:8	
			Taste	
Overall	Over_T	Not perceivable–Strongly perceivable	All perceptible taste	Taste intensity after the first swallow
Bitter	Bit_T		Caffeine solution: 0.17 g/L (medium perceivable)	
Salty	Sal_T		Sodium chloride solution: 0.98 g/L (medium perceivable)	
Sour	Sou_T		Citric acid solution: 0.31 g/L (strongly perceivable)	
Sweet	Swe_T		Sucrose solution: 4.32 g/L (weakly perceivable)	
Cereal	Cer_T		Damp mixture of oats, wheat, rye, barley, spelt (Kölln Multikorn-Flocken)	
Nutty	Nut_T		Shredded nut mixture of cashew, walnut, hazelnut, almond (Seeberger)	
Milk	Milk_T		Fresh cow's milk, fat content 3.5%	
Cooking	Cook_T		Whole milk heated to steaming and cook 10 min	
Vanilla	Van_T		Pure vanilla extract diluted with water in a ratio of 1:8	
Aftertaste	After_T		Intensity overall	Intensity of aftertaste in total, 5 s after swallowing
			Texture	
Astringent	Ast_TX	Not perceivable–Strongly perceivable	Chemical sensitivity factor on the tongue/oral cavity described as dry or astringent 0.1% Alum solution	Texture intensity after the second swallow
Viscosity	Vis_TX	Liquid–Viscous	Viscid appearance is perceived when flowing as the product moves over the tongue and palate. Water = 0, Whipping cream = 100	
Chalky	Chal_TX	Not perceivable–Strongly perceivable	Mealy, powdery sensory impression Calcium carbonate tablets ground into powder and blended with water at a ratio of 1:10	

[1] The definition was suggested and accepted by the panelists; abbreviations: _A = appearance, _O = odor, _T = taste, _TX = texture.

2.5. Electronic Tongue

This study used an electronic tongue (e-tongue) α-ASTREE Liquid Taste Analyzer (Alpha M.O.S., Toulouse, France) with an autosampler with 16 sample positions. The e-tongue consists of an array of seven different liquid sensors mounted around an Ag/AgCl reference electrode [38]. A sensor set consisting of seven sensors was used, which was developed to analyze food (coded: AHS, PKS, CTS, NMS, CPS, ANS, SCS). According to the manufacturer, three tests ("conditioning", "calibration", and "diagnostic") must be passed in order to acknowledge that all sensors are working properly. Before the analysis, these three tests were performed on each new food product. The "conditioning" and "calibration" steps were performed using an aqueous solution of 0.01 mol/L hydrochloric acid. For the last step, "diagnostic", sodium-L-glutamate (0.01 mol/L), sodium chloride (0.01 mol/L), and hydrochloric acid (0.01 mol/L) solutions of ultrapure water were prepared. For the measurements, the sensors ran into the sample solution for 120 s, and the last 20 s of the analysis were used for statistical evaluation. After each measure, the sensors were cleaned in a beaker with ultrapure water for 10 s [41,42]. This collection method was looped 12 times for each sample, with the first two measurement results being omitted during the evaluation process. All PBMA sample solutions were prepared from freeze-dried material with ultrapure water (1% w/v), filled in centrifuge tubes, heated in a water bath to 95 °C for 10 min, and centrifuged at 9000 rpm for 10 min at 20 °C (Heraeus Megafuge 16R Centrifuge, Thermo Fisher Scientific, Waltham, MA, USA). The clear liquid was collected and filtered (615 ¼ filter, Macherey-Nagel, Düren, Germany) before being analyzed.

2.6. Volatile Compounds

The beverages were shaken in their original packaging and then poured into 50 mL centrifuge tubes and stored at −20 °C until the analyses. The samples were defrosted overnight at 5 °C for analysis. Subsequently, 2 mL were pipetted into a 20 mL glass vial already filled with 4 g of NaCl for saturation, closed with a polytetrafluoroethylene (PTFE)-coated silicone rubber septum. The volatiles were extracted by headspace solid-phase-micro-extraction (HS-SPME) with a 100 mm polydimethylsiloxane (PDMS) fiber (PAL System, CTC Analytics, Zwingen, Switzerland). Before sampling, the incubation time was 30 min at 60 °C, with an agitator speed of 500 rpm. The sample extraction time was 40 min at the same temperature and in shaking mode. Thermal desorption in the injector was performed for 3 min at 250 °C (splitless mode), followed by 9 min in split mode (split ratio 1:10). Each sample was analyzed in duplicate. The GC-2010 Plus (Shimadzu Deutschland GmbH, Duisburg, Germany) was used for the separation and identification of the analytes. Helium was used as a carrier gas at a 1 mL/min flow rate. The column temperature program was as follows: 40 °C initial temperature held for 5 min, raised to 100 °C at a rate of 10 °C/min in the same shaking mode, further raised to 220 °C at a rate of 5 °C/min held for 5 min and finally raised to 250 °C at a rate of 15 °C/min. The total analysis time was 44 min. Analyte desorption took place in the GC injection port at 250 °C for 3 min in splitless mode, and the fiber was kept in the injection port for 5 min more for cleaning. The mass analyzer was set on scan mode, and the recorded ions were m/z: 35 to m/z: 350. MS source and MS Quad were operated at 250 and 130 °C, respectively. There were 366 compounds identified with the National Institute of Standards and Technology 14 library (NIST, MD, United States). The evaluation of the results was performed through databases PubChem [43]; Food Flavourings Version 3.3, an informational tool on the flavoring substances approved for use in food in the EU [44]; and the database of food compounds, the FooDB, Version 1.0 [45], which is the largest public repository of food compounds and contains a large set of ca. 26,000 molecules.

2.7. Statistical Analyses

The data from the study were statistically analyzed using SPSS® statistical software (IBM SPSS Statistics, Version 26.0, Armonk, NY, USA) and Microsoft Excel® (Microsoft Office Professional Plus, 2013). The results of the instrumental sensory and human sensory evaluations were analyzed using one-way and two-way analysis of variance (ANOVA), followed by Tukey's post hoc test ($p < 0.05$). Correlation analysis was conducted to determine the relationships among the attributes (Pearson correlations). Principal component analysis (PCA) was performed for the sensory evaluation and volatile compound analysis using Statistica version 13.3 (TIBCO Software Inc., Chicago, IL, USA). PCA was used to identify redundant terms and determine which terms best described each sample. The PCA biplots provided a visual representation of which terms were related and described the samples. Only GC-MS data were incorporated for which databases could substantiate odor-active key compounds ($n = 43$).

3. Results

3.1. Macronutrients (Big 7) and Nutri-Score

The list of nutritional labels, the so-called "Big 7", which the manufacturer must indicate on the product, was used to compare the products with regard to their macronutrients. In the case of missing information, such as dietary fiber, which is not part of the mandatory information but is important for the calculation of the Nutri-Score, the mean value was generated from the available product data, denoted by $^{\#\#}$ in Table 1.

The comparison of the energy content of the different PBMAs showed that almond drinks had on average the lowest energy content, with an average of 21.8 kcal/100 g compared to 24.0 kcal/100 g given in the database. Soy and oat drinks followed, while cow's milk had the highest with 53.1 kcal/100 g (Table 1). Total fat and SFA contents were lower in PBMAs than in cow's milk. Both carbohydrate and sugar content in cow's milk was about 5.0 g/100 g. For PBMAs, the oat drinks showed the highest proportion of both macronutrients with 7.36 g/100 g and 4.2 g/100 g, and 7.86 g/100 g and 2.83 g/100 g, respectively, among the products in the databases. In particular, the almond drinks had the lowest carbohydrate and sugar contents with 0.64 g/100 g and 0.6 g/100 g, respectively. Here, a wide variety of products is shown, for example, four almond drinks had a low content of carbohydrates and sugars, but in one product (ABA), the content was quite high. The highest levels of dietary fiber could be found in oat drinks. The average protein content of the soy drinks was 3.02 g/100 g, and 3.15 g/100 g among the products in the databases, which was close to that of cow's milk at 3.37 g/100 g. The other PBMAs, especially the almond drink, had on average significantly lower protein contents (Table 1).

The calculation of the nutritional properties of the PBMAs demonstrated that the soy-based beverages had the best Nutri-Score with a score A (Table 1). Four of the five oat drinks had score B, one had score A. The oat products from the database received an average of score A, though. The highest Nutri-Score was observed in almond drinks (score B). The data from the database for cow's milk also gave a score B.

3.2. Vitamins and Minerals Evaluations

Table 3 shows the mean percentage of the recommended daily intake according to the D-A-CH (Germany, Austria, Switzerland) reference values for the determined water- and fat-soluble vitamins as well as the minerals, separated by gender and different age groups (19–25 years and $\geq$65 years). If no other recommendations were given for the male gender, the recommendations for the female gender should apply. The different age groups were chosen, because the motivation to consume PBMAs may vary by age group. Database values for PBMAs and cow's milk were based on information from the databases referenced.

PBMAs could meet the daily requirements for fat-soluble vitamins D and E equally well or significantly better than cow's milk, regardless of age group or gender (Table 3). For water-soluble vitamins, almond drinks were generally lower than oat and soy drinks. The database values were higher than the values determined for the soy drinks. Cow's milk better covered the need for vitamins B_2, B_3, and B_6. Here, the values obtained by PBMAs were lower than those in the PBMAs database, although the soy beverages scored the highest values compared to those of the other two plant-based alternatives. The analyzed products covered the vitamin B_{12} requirement better than those in the database. The exception was the almond drinks, which showed lower contents.

Table 3. Coverage of the daily vitamin and mineral requirements by PBMA drinks compared to database values *. Percentage based on D-A-CH reference value recommendations, per 100 g of food, and related to gender and age (19–25 years and ≥65 years).

			Almond * *n* = 6 [%]	**Almond** *n* = 5 [%]	**Oat *** *n* = 11 [%]	**Oat** *n* = 5 [%]	**Soy *** *n* = 38 [%]	**Soy** *n* = 5 [%]	**Cow's Milk *** *n* = 55 [%]
				D-A-CH reference values female, 19–25 years					
Vitamin D	20	µg	4.50	nd	2.64	3.00 [a]	1.58	2.38 [b]	2.71
Vitamin E	12	mg	20.18	8.75	4.04	5.26	6.72	2.38	0.53
Vitamin B_1	1	mg	2.66	0.32	2.73	3.05	5.95	2.08	2.10
Vitamin B_2	1.1	mg	10.86	7.37	9.27	8.99	14.61	8.86	17.30
Vitamin B_3	13	mg	0.84	0.95	2.32	0.44	2.87	0.88	2.58
Vitamin B_6	1.4	mg	0.64	0.52	6.54	1.00	7.80	2.06	2.57
Folic acid	300	µg	0.33	1.34	1.94	1.98	8.11	3.06	3.09
Vitamin B_{12}	4	µg	11.04	6.55 [b]	4.55	11.45 [b]	8.03	12.92 [c]	11.12
Na	1500	mg	4.09	3.71	2.34	2.74	2.60	3.47	2.91
K	4000	mg	1.09	1.22	0.86	0.72	4.11	4.61	3.90
Mg	310	mg	2.59	2.57	4.00	1.09	6.00	6.76	3.71
Ca	1000	mg	14.67	10.26	8.70	4.77	9.31	11.01	12.06
Fe	15	mg	1.56	0.12	2.52	nd	3.77	1.99	0.73
P	700	mg	1.63	7.30	5.38	6.20	8.29	12.97	13.32
Cu	1.3 (1.0–1.6)	mg	1.92	3.91	1.54	10.33	8.67	17.48	0.77
Zn	8.5 (7–10)	mg	1.75	1.26	3.34	0.89	1.74	4.45	4.79
				D-A-CH reference values female, ≥65 years					
Vitamin E	11	mg	22.02	9.55	4.41	5.73	7.34	2.59	0.58
Vitamin B_2	1	mg	11.95	8.11	10.20	9.89	16.07	9.75	19.02
Vitamin B_3	11	mg	0.99	1.12	2.75	0.52	3.40	1.04	3.05
Mg	300	mg	2.68	2.66	4.13	1.12	6.2	6.99	3.84
Fe	10	mg	2.35	0.18	3.78	nd	5.65	2.99	1.1
				D-A-CH reference male, 19–25 years					
Vitamin E	15	mg	16.14	7.00	3.23	4.20	5.38	1.90	0.43
Vitamin B_1	1.3	mg	2.05	0.24	2.10	2.35	4.58	1.60	1.62
Vitamin B_2	1.4	mg	8.54	5.79	7.28	7.06	11.48	6.96	13.59
Vitamin B_3	16	mg	0.68	0.77	1.89	0.35	2.34	0.72	2.10
Vitamin B_6	1.6	mg	0.56	0.45	5.73	0.88	6.82	1.80	2.25
Mg	400	mg	2.01	2.00	3.10	0.84	4.65	5.24	2.88
Fe	10	mg	2.35	0.18	3.78	nd	5.65	2.99	1.10
Cu	1.25 (1.0–1.5)	mg	2.00	4.07	1.60	10.74	9.01	18.18	0.80
Zn	13.5 (11–16)	mg	1.10	0.80	2.11	0.56	1.10	2.80	3.02
				D-A-CH reference male, ≥65 years					
Vitamin E	12	mg	20.18	8.75	4.04	5.26	6.72	2.38	0.53
Vitamin B_1	1.1	mg	2.42	0.29	2.48	2.78	5.41	1.89	1.91
Vitamin B_2	1.3	mg	9.19	6.24	7.84	7.61	12.36	7.50	14.63
Vitamin B_3	14	mg	0.78	0.88	2.16	0.40	2.67	0.82	2.39
Mg	350	mg	2.30	2.28	3.54	0.96	5.31	5.99	3.29

* Calculated mean values from AUSNUT, Fineli, USDA, and BLS databases; recommendations for vitamin D, folic acid, B_{12}, and Na, K, Ca, P correspond to both genders; [a] *n* = 1, [b] *n* = 2, [c] *n* = 3, nd = not detected.

Compared to cow's milk, the mineral requirement was similarly well-covered by soy drinks. The higher copper (Cu) levels were analyzed in the oat and soy drinks. In addition, the iron (Fe) content in the database values of the PBMAs was higher than that of cow's milk. The database values for the calcium (Ca) requirement of the PBMAs were also higher than the analyzed values, except for the soy drinks (Table 3).

3.3. Sensory Evaluation

Raw material sources significantly influenced the sensory quality for all three product groups (almond, oat, soy). Considering all 23 attributes evaluated by the sensory panel, out of the total 15 PBMAs, five per product group, significant differences could be calculated for eight attributes, as shown in Figure 1A. As mentioned, the intent was to use the same evaluation form for several beverages. However, some of the uses of the various attributes differed significantly, such as the nutty odor and taste of the almond drinks to those of the other products, indicating that some terms were more product-specific. Figure 1B–D gives a more detailed overview of the significantly different sensory attributes of the selected products based on the raw material sources almond, oat, and soy.

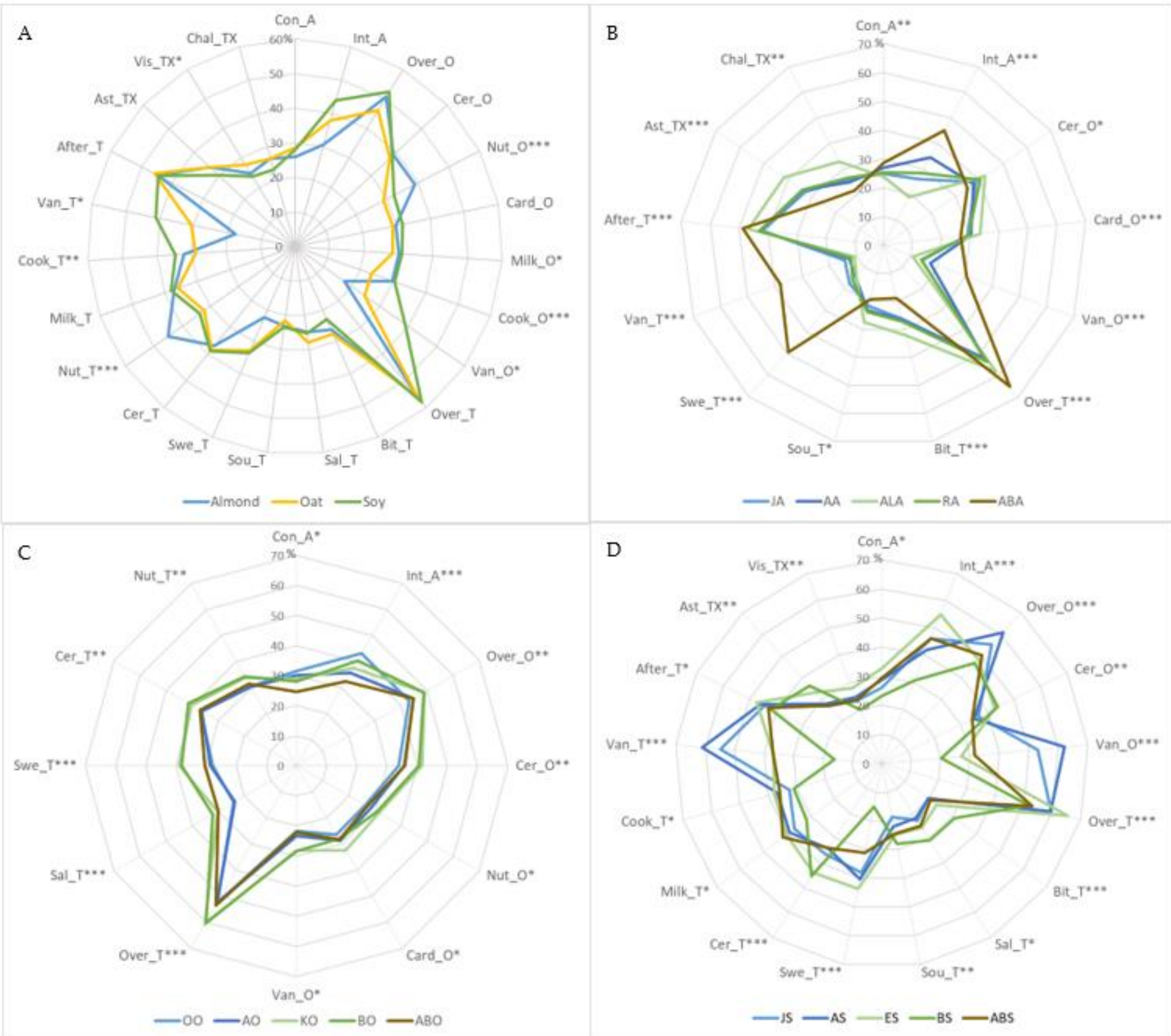

Figure 1. Spider diagram for sensory evaluation using quantitative descriptive analysis (QDA) of PBMAs; it shows the comparison of three raw materials with five products each, here with all attributes (**A**), and the significant attributes of almond drinks (**B**), oat drinks (**C**), and soy drinks (**D**); blue lines—conventional products, green lines—organic products, brown lines—barista-style products; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; for abbreviations of the products, see Tables 1 and 2.

For the five almond drinks (Figure 1B), 13 significantly different attributes were assessed, with two products differing strongly. On the one hand, the barista-style product (BS) was perceived as significantly darker (Int_A) and rated higher than the other products in the attributes of sweetness (Swe_T) as well as vanilla odor (Van_O) and taste (Van_T). On the other hand, the product ALA was perceived as the lightest (Int_A) and rated the highest in bitter taste (Bit_T) as well as astringent and chalky mouthfeel.

The evaluation of the oat beverages showed significantly different attributes. The two organic products were scored very similarly as well as the two conventional products, except for the attributes for appearance. The oat-based barista-style product was evaluated between these two product categories (Figure 1C). Both organic products were almost consistently evaluated higher on the rating scale than the conventional products. In addition to higher cereal and nut notes (Cer_O, Nut_O, Cer_T, Nut_T), the drinks had stronger overall odor and flavor (Over_O, Over_T) and higher sweetness and saltiness (Swe_T, Sal_T). Oat drinks tended to have a watery texture (Vis_TX) compared to that of the two other product groups. In addition, these products were often characterized by their darker, browner, and grayer appearance (Int_A) (Figure 1A).

Soy drinks had the most diverse sensory attributes and showed the most significant differences in 17 out of 23 attributes. Like the oat drinks, the panel evaluation showed a distinction between organic and conventional product categories for several attributes, most significantly for vanilla odor and flavor (Van_O, Van_T) (Figure 1D). The organic products were rated the highest in the attributes cereal note (Cer_O, Cer_T) as well as the basic tastes of bitter (Bit_T), salty (Sal_T), and sour (Sou_T), and the mouthfeel astringent (Ast_TX). The BS product further stood out with a low rating of vanilla note (Van_O, Van_T) and sweet taste (Swe_T). Interestingly, soy-based beverages were more associated with a milk odor and taste (Milk_O, Milk_T) than the other two product groups and were characterized by a darker, reddish- to brownish-colored appearance (Int_A) (Figure 1A).

3.4. Comparison of E-Tongue Results and Sensory Evaluation

The e-tongue measured taste in relation to the five basic human sensory tastes (sweetness, sourness, bitterness, saltiness, and umami) in the PBMAs. The e-tongue results for sweetness, sourness, and saltiness were compared to the perceived results of the trained sensory panel. The sensory panel results and the e-tongue measurement data showed a significant positive correlation for sweetness, sourness, and saltiness for all PBMAs (Figure 2).

3.5. Volatile Profile of PBMAs

A total of 366 volatile compounds were detected by GC-MS, of which 94 compounds had ≥75% qualitative similarity and were present in FooDB [45]. These identified compounds belonged to different chemical classes, which were classified into the following groups: alkanes (26%), acids (19%), aldehydes (18%), alcohols (11%), organic compounds (11%), aromatic/cyclic compounds (6%), furans (4%), pyrazines (3%), and esters (2%). When comparing specific compounds, some were found in all raw material groups, such as hexanal, acetic acid, pentanal, and furan, 2-pentyl-. The number of compounds in the different substance classes of volatile compounds and their percentage content within each raw material group as well as the average percentage qualitative similarity of the compounds are presented (Table 4). The almond drinks had the highest content of aldehydes and alkanes, and the highest percent similarity was in the pyrazines with 93%, which, however, only occurred once here. In oat drinks, most substances were found in the groups of acids and alkanes. The qualitative similarity was <90% in all groups, except for the alkanes with 94.8%. Organic compounds, alkanes, and acids were the chemical classes that occurred most often in soy drinks. Here, a qualitative similarity of >90% was found in five of the total nine classes. Of these substances, 43 odor-active key compounds were identified in the databases of PubChem [43] and FooDB [45] as well as in studies [23,46–51] (Table 5).

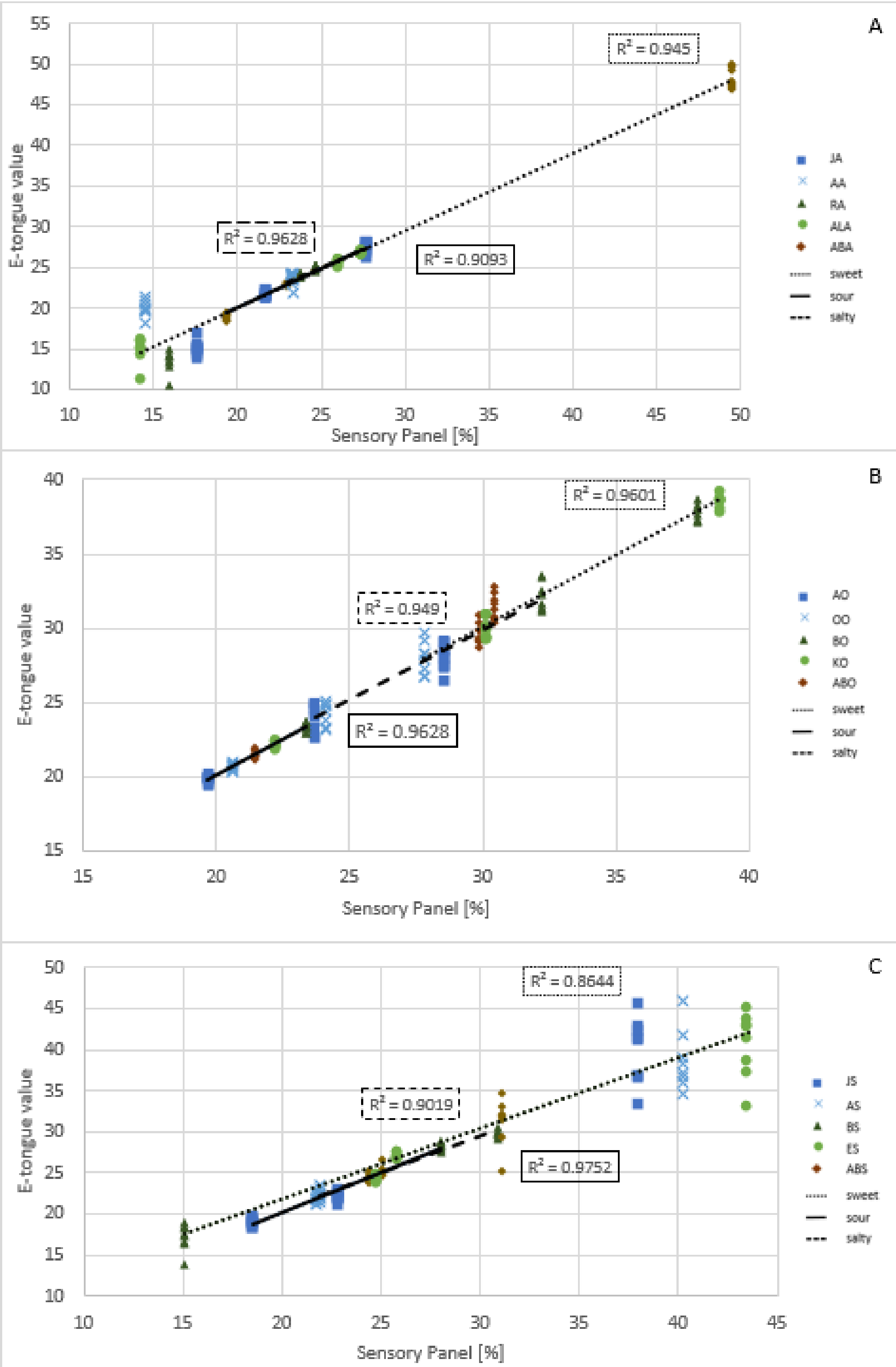

Figure 2. Comparison of sensory results and e-tongue values for the attributes sweet, sour, and salty (Pearson correlation) in almond drinks (**A**), oat drinks (**B**), and soy drinks (**C**); blue symbols—conventional products, green symbols—organic products, brown symbols—barista-style products; correlations were significant with $p < 0.05$.

Table 4. The number of compounds in the different substance classes of volatile compounds, their percentage content within each raw material group, and the average percentage qualitative similarity (≥75%) of the compounds.

	Acids	Alcohols	Aldehydes	Alkanes	Aromatic/ Cyclic Compounds	Esters	Furans	Organic Compounds	Pyrazines
Almond (n/%)	3/8.6	6/17.1	8/22.9	8/22.9	4/11.4	2/5.7	1/2.9	2/5.7	1/2.9
%-Qualitative similarity	84.7	91.7	87.9	92.1	83.3	76.0	76.0	82.0	93.0
Oat (n/%)	6/24.0	1/4.0	4/16.0	9/36.0	1/4.0	0/0	2/8.0	2/8.0	0/0
%-Qualitative similarity	87.3	88.0	86.3	94.8	83.0	0	85.5	85.0	0
Soy (n/%)	9/26.5	3/8.8	5/14.7	7/20.6	1/2.9	0/0	1/2.9	6/17.6	2/5.9
%-Qualitative similarity	88.8	92.0	87.6	91.0	97.0	0	97.0	80.5	92.0

Table 5. Odor-active compounds (*n* = 43) with a percentage qualitative similarity of ≥75% in the PBMA drinks.

Class	Compound	Odor Impression [a]	Described in PBMA [b]	Almond					Oat					Soy				
				AA	JA	ALA	RA	ABA	AO	OO	BO	KO	ABO	AS	JS	ES	BS	ABS
Acids	Tetradecanoic acid	Burnt, cheese, harsh									83	84		89	93	93	92	93
Acids	Dodecanoic acid	Coconut, fatty, metal													89	89		
Acids	Oleic Acid	Fatty												89	89	89		87
Acids	Hexadecanoic acid	Fatty							81		85	89	94	95	95	95	94	95
Acids	Acetic acid, methyl ester	Honey, fruity, green	5					86										
Acids	Acetic acid	Sour, fruity, vinegar		98		97	91	98	98	95	97	98	98	97	86	95	97	93
Acids	Pentadecanoic acid	Waxy							80					89	91	90		91
Alcohols	1-Butanol, 3-methyl-	Banana, floral, fruity, malt, wheat				91											82	
Alcohols	1-Octanol	Bitter almond, fatty, green, rose	3			96												
Alcohols	1-Heptanol	Coconut, green, mushroom, nutty, woody	1, 2, 3, 4			91												
Alcohols	1-Hexadecanol	Flower, wax										88						
Alcohols	1-Pentanol	Fruity, green, grain, mushroom, vanilla	1, 2, 3, 4			93												
Alcohols	1-Hexanol	Green, beany, fruity, grain, nutty, wheat	3, 5, 4, 1, 2			84										96	97	
Alcohols	1-Octen-3-ol	Mushroom, cooked bean, fatty	1, 2, 3, 4, 5, 6													88	97	
Alcohols	Phenylethyl Alcohol	Rose, floral, fruity, honey	5			95												
Aldehydes	2,4-Decadienal	Citrus, fatty, green	2, 3, 4, 5, 6			87					87						89	
Aldehydes	Nonanal	Almond, fatty, green, lemon, rose, soapy	1, 2, 3, 4, 5			90												
Aldehydes	Benzaldehyde	Almond, malt, woody	2, 3, 4			97		91										
Aldehydes	Piperonal	Anise, coconut, flower, vanilla												93				
Aldehydes	Benzaldehyde, 3-methoxy-	Anise													82			

Table 5. *Cont.*

Class	Compound	Odor Impression [a]	Described in PBMA [b]	Almond					Oat					Soy				
				AA	JA	ALA	RA	ABA	AO	OO	BO	KO	ABO	AS	JS	ES	BS	ABS
Aldehydes	Benzaldehyde, 4-methyl	Cherry, fruity, sweet	2, 3						83									
Aldehydes	Octanal	Citrus, fatty, green, soap	2, 3, 4, 5			96												
Aldehydes	Hexanal	Green, fruity, leafy	1, 2, 3, 4, 5, 6	75		96					90						93	88
Aldehydes	Hexanal, 3-methyl-	Green			78													
Aldehydes	Pentanal	Green, almond-like, cooked beans, nutty	1, 2, 3, 4, 5			93			82				85		81			
Aldehydes	Heptanal	Green, citrus, nutty, rancid	1, 2, 3, 4, 5			89												
Alkanes	Eicosane	Waxy						82										83
Alkanes	Heneicosane	Waxy									95			90		93	88	89
Alkanes	Tetradecane	Waxy, sweet, fusel-like	3, 4	95		96	96	95	96	96	97	80	97	96	96	95	95	96
Alkanes	Pentadecane	Waxy		96	96						95	96				95	95	
Aromatic/Cyclic compounds	D-Limonene	Citrus, mint, fruity	2, 3					95										
Aromatic/Cyclic compounds	3-Carene	Lemon	9			77												
Aromatic/Cyclic compounds	Phenylephrine	Bitter				81												
Aromatic/Cyclic compounds	Acetylbenzoyl	Savory, buttery, honey						80										
Aromatic/Cyclic compounds	Vanillin	Vanilla	5								79	83	81	97	95			
Ethers	1,1-Dimethoxydecane	Citrus, green, herbal			77													
Furans	Furan, 2-pentyl-	Bean, floral, fruity, green	2, 3, 4, 5			76					94					95	97	
Organic compounds	gamma.-Dodecalactone	Apricot, floral, fruity, peach															80	
Organic compounds	9-Octadecenal	Dairy, fatty														79		
Organic compounds	Octadecanoic acid	Fatty												88	86	79	89	86
Organic compounds	Propyl propionate	Fruity, pineapple, banana													78			
Pyrazines	Pyrazine, 2,5-dimethyl-	Nutty, chocolate-like	2, 4, 5											91				92
Pyrazines	Pyrazine, 2,6-dimethyl-	Nutty	9					93										93

[a] Odor impression was described in PubChem or FooDB; [b] References that have described compounds and odor impression in PBMA: 1—Xia et al. [46], 2—Manousi et al. [47], 3—Klein et al. [48], 4—Pérez-González et al. [23], 5—Nedele et al. [50], 6—Kaneko et al. [51]; blue highlighted—conventional products, green highlighted—organic products, brown highlighted—barista-style products; the color scale ranges from 75% (red) to 98% (dark green) and corresponds to qualitative similarity.

Combining the data from the sensory panel with those from the analysis of volatile compounds showed which compounds influenced the odor and taste of certain products (Figure 3). The highest content of aldehydes characterized the almond beverages, including the benzaldehyde characteristic of almonds (Table 4). A relatively high number of alcohols were also detected in almond drinks, e.g., phenylethyl alcohol, 1-heptanol, and 1-octanol were identified only in almond drinks (Table 5). These results are confirmed by Pérez-González et al., which states that the aroma profile of almond beverages is mainly composed of aldehydes, ketones, and alcohols [23]. The results from the sensory analysis showed that these compounds led to a nutty taste and odor. The oat beverages generally differed from other beverages by a higher number of alkanes compounds (Table 4). Thus, many compounds from this chemical group were associated with waxy attributes (Table 5). Overall, few volatile compounds were found in these PBMAs. Overall, oat beverages showed great homogeneity in the sensory description (Figure 3). The soy beverages had high acids levels (Table 4), although they were found in slightly smaller amounts in the other raw materials groups. These compounds often had an acidic odor, which is probably why they led to the odor attributes milk (Milk_O) and cooked (Cooked_O) in soy beverages (Figure 3). Vanillin was detected in the highest qualitative similarity and quantity in soy beverages, overlapping with the sensory evaluation (Vanilla_O, Vanilla_T).

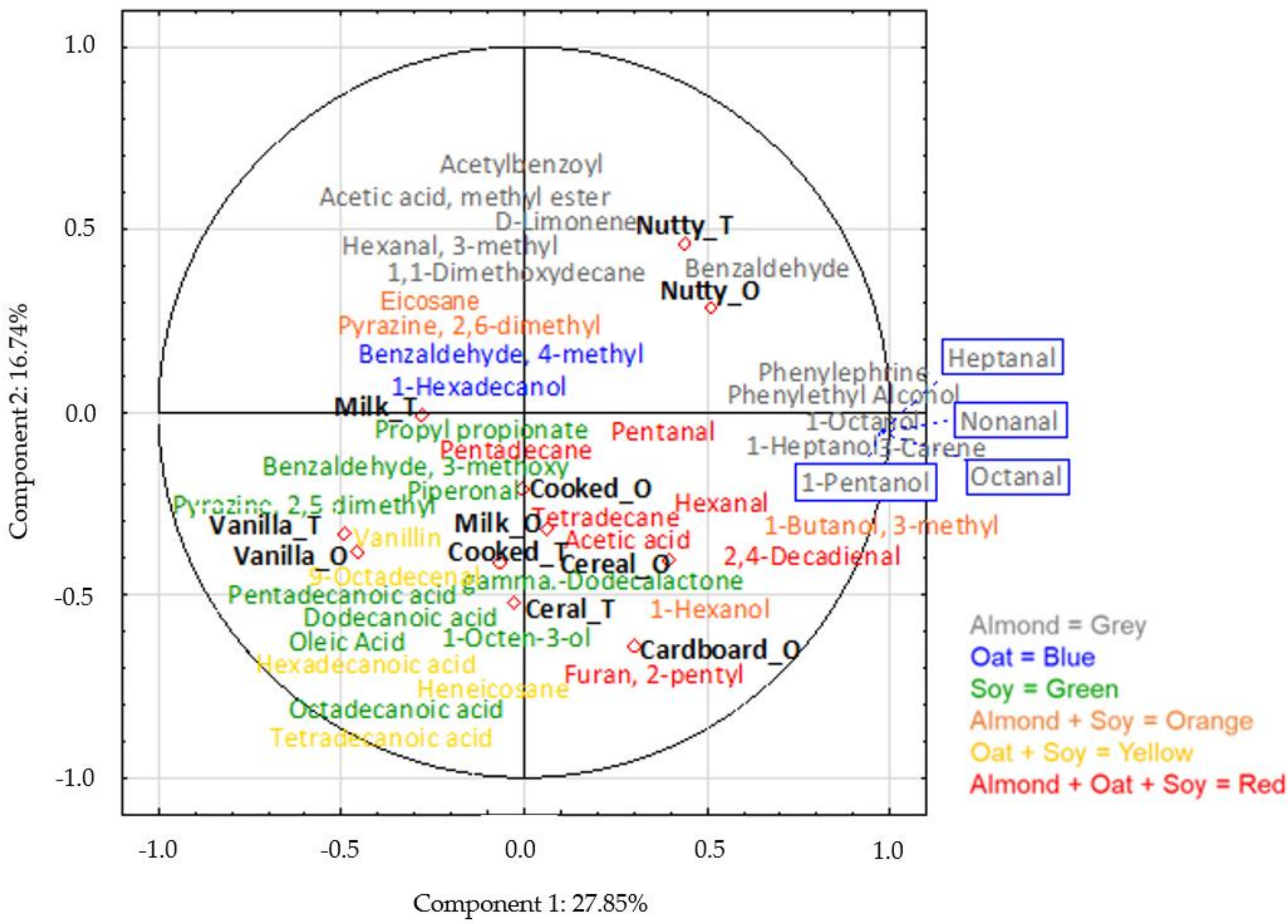

Figure 3. PCA results for the volatile compounds (n = 43) compared with the mean sensory data, including odor (_O) and taste (_T) attributes (black text, red squares); the volatiles are shown in different colors depending on the source of the raw materials in which they could be detected. For a description of odor impressions, see Table 5.

4. Discussion

4.1. Nutritional Properties

The nutritional properties of a variety of PBMAs and cow's milk were compared for macronutrients (Table 1) and micronutrients (Table 3). This comparison showed significant differences in the nutritional value of the various beverages. Soy drinks had a similar protein content to that of cow's milk, whereas almond and oat drinks had much lower values. There were also differences in amino acid composition between the different plant-based raw materials and cow's milk. The study by Gorissen et al. [52] showed the essential amino acid content of raw plant material in total 13.7 g/100 g in oats, 19.9 g/100 g in soy, and 30.3 g/100 g in cow's milk, with similar differences for non-essential amino acids. Considering that in PBMAs the raw material content was between 2% and 12%, this could have nutritional effects when regularly consumed. Therefore, combinations of different plant-based protein isolates are useful, as they could increase the evaluation of the amino acid profile, "protein digestibility-corrected amino acid score" (PDCAAS) of the product, which was close to that of cow's milk. Some commercial oat beverages were currently already supplemented with pea isolates because they were rich in essential amino acids (30.3 g/100 g) and non-essential amino acids (38.6 g/100 g) [52].

Based on the D-A-CH reference values, there were significant differences in the various plant-based beverages in the coverage of the daily requirement of vitamins and minerals (Table 3). Reference was made explicitly to the different age groups and gender, as the motivations for consuming these plant-based drinks often differed. Thus, on the one hand, the potential benefit for the environment [7] and, on the other hand, health aspects [19]. When comparing the data shown here with results from other studies [53–57], the same results are obtained with slight variations. Cow's milk is a rich source of fat- and water-soluble vitamins and compared to PBMAs, it contains higher amounts of vitamins B_2, B_3, and B_6. Fortified alternative products could be an important source of vitamins if they achieve levels similar to those of cow's milk. A study by Scholz-Ahrens et al. [58] shows the major importance of vitamin B_{12} supply for bone health and neuronal function and that people over the age of 60 are at an increased risk of having a deficiency.

Cow's milk often has a higher mineral content than the plant-based beverages analyzed here. Therefore, supplementation was applied to most products [59], except for products produced according to organic certification [60]. The supplementation with minerals increases the nutritional value of these products. Astolfi et al. [55] found that cow's milk has higher Ca, P, Mg, Na, and K content than PBMAs do. For Ca and P, this was also confirmed by the analyses shown here (Table 3).

In addition to the low mineral content, legume-based beverages may contain antinutrients such as phytic acid, oxalates, lecithin, and saponins. These reduce the body's absorption and digestibility of essential minerals such as Ca, Fe, Mg, Zn, and Cu. Beyond that, they bind these compounds and form insoluble complexes [19,20]. The study by Borin et al. [61] focused on the risk factors for kidney stones and chronic kidney diseases concerning PBMAs. The authors were able to show that oat, rice, and soy drinks are comparable to milk in terms of kidney stone risk factors, while almond and cashew drinks had a potentially higher stone risk factor, as the highest oxalate concentration was found in almond drinks. For patients with chronic kidney disease, coconut beverages are a good milk alternative because they are low in oxalate and contained low K and Na levels [60].

Another undesirable property is the allergic potential, especially in soy and almond drinks [19,21,61]. The proteins that could trigger allergies, especially tree nuts and soy, are among the eight most common food allergens [21]. Furthermore, the authors wrote that almost 14% of people allergic to cow's milk also report reactions to soy protein. The presence of gluten in PBMAs, in oat and other cereal-based beverages, is tolerated by most people but may have adverse health consequences in people with gluten intolerance, especially celiac disease [62]. Pea allergies are rare and therefore not extensively studied, so there is limited information on this [63].

Among PBMAs, legume-based beverages have a protein content comparable to that of milk and the highest PDCAAS, which is related to protein digestibility and indicates the quality of the protein profile [20]. Furthermore, soy drinks have a good ratio of micro- to macronutrients and are closest to the values of cow's milk. Therefore, people who include more plant-based foods in their diets should take special care to maintain a balance of essential vitamins, minerals, and amino acids. Unfortunately, there are very few comprehensive or no long-term studies on the health effects of PBMAs, but studies on the raw material showed some health benefits, such as for oats and almonds [64].

In accordance with the NOVA classification, PBMAs could also be categorized as organic products (NOVA group 3) or conventional products (NOVA group 4) [24,25]. Products with an organic label can only be produced according to the guidelines for organic products in Europe, which also regulate the use of additives or flavorings [59]. In the production of PBMAs, as with UPFs, natural raw materials are broken down, and the processing changes the food matrix. Depending on the raw material, different processing steps are required, such as crushing, separation, enzymatic or chemical hydrolysis, blanching, thermal processes, homogenization, and formulation with the addition of functional ingredients such as flavors, colorants, preservatives, stabilizers, thickeners [7,11,58]. The processing steps necessary for almond drinks are described in a study by Grundy et al. [65]. The modified matrix is recombined, and additives are used, which affects the availability of nutrients, energy, secondary phytochemicals, and digestibility [65,66]. A study by Drewnowski [67] showed that out of the total 641 PBMAs, 90% could be classified as UPFs. It should be noted that only data from the USDA Agricultural Research Service database were taken here. On average, the products had a much higher Nutri-Score of 9.63 (score C) than the products in this study, where the evaluated products had a Nutri-Score of −0.5 (score A/B). This shows that there were many different products in an expanding market and that the product groups and the products are very heterogeneous. Increased disease risks with negative effects of cardiometabolic diseases, cerebrovascular diseases, depression, frailty, irritable bowel syndrome, and cancer were associated with UPFs, as shown by recent reviews and meta-analyses [68–70].

In a study by Romero Ferreiro et al. [71], it was clarified that the Nutri-Score classifies foods according to their nutritional quality but does not consider aspects such as degree of processing. Thus, the authors could find UPFs in all Nutri-Score categories, for example, 26% with a Nutri-Score A and 51% with a Nutri-Score B. Therefore, a complementary label indicating the degree of processing would be helpful for the consumer.

4.2. Sensory Characteristics

More than 40 years ago, the first sensory studies on legume-based beverages were conducted, with the results that the products were similar to cow's milk in color and viscosity, but were all deficient in odor and taste [72]. Of the ten legume species at that time, lima, mung, and pea bean were rated equally high, and soybeans scored significantly lower. There have been further developments in many areas, from breeding to food technology. Thus, soy products are gaining importance today due to their high-quality protein and are in high demand by consumers worldwide. Chambers et al. [73] developed a lexicon through a descriptive analysis with a trained sensory panel that can be used to characterize soy drinks. However, the authors discuss that their study results cannot be considered exhaustive due to the variety of products on the growing market and the continuous development of products.

Figure 1A shows the comparison of three raw materials (almond, oat, soy) with five products each, here with all sensory panel attributes requested. Since there were only a few significant differences here, it is again clear that the products should be evaluated according to the raw material source since there is a high degree of heterogeneity. Figure 1B–D show that there were significant differences between organic and conventional PBMAs. It is also shown here that more negative attributes such as bitterness and astringency were associated with organic products. A recent study by Hoppu et al. [74] cites several consumer studies [75–77] asking whether there are sensory differences between organically and conventionally grown vegetables or their products. None of these studies measured significant differences. The masking of bitterness has been studied the most in consumers with high sensitivity to bitter taste. Hoppu et al. [73] pointed out studies in which taste interactions in vegetables and their products, and aqueous solutions with salts, sucrose, and sweeteners, can significantly mask bitterness.

In soybean beverages, bitterness and astringency were also considered negative properties [78,79]. Furthermore, Torres-Penaranda and Reitmeier [78] found that adding sugar resulted in desirable flavor changes by reducing the attributes of bitterness and astringency. In the results for almond drinks (Figure 1B), this was again evident, as "sweet" products were rated less "bitter" and "astringent". For the soy drinks (Figure 1D), similar conclusions could be reached only for the product "ES", which was rated high in sweetness and also in bitterness and astringency, so the masking did not seem to work optimally. Here, the organic products had highest soybean content with 11.0% and 9.4%, so this could be related to the more negative attributes (astringent, bitter).

A study by Yang et al. [80] clearly shows that cultural influences are also decisive for the product development of PBMAs, especially in soy beverages. The authors found that the typical bean-like taste of soy milk is important for "traditional" soy consumers from Asia and is strongly associated with the product. PBMAs are composed of a complex of proteins, lipids, and carbohydrates combined with several micro-components, making these products a heterogeneous food matrix.

4.3. Comparison of the Results of Electronic Tongue and Sensory Evaluation

An e-tongue was used to classify basic flavors in PBMAs and compare the results with those of the sensory panel. This automatic, qualitative analysis of highly complex samples rapidly detected product-specific and characteristic properties. As the results of the study by Pascual et al. [81] showed, it is possible to make a distinction between PBMAs based on different raw materials and through different manufacturing processes (handmade or industrial).

Since sweetness is a very relevant parameter in plant-based drinks and soy drinks are generally associated with the attribute "salty", it received in this study as well as in the study of Pascual et al. [81] lower values for the parameter "sweet". Almond drinks received the highest ratings for sweetness in both studies, with the oat drinks falling between the two drinks. When adding the product data of the Big 7 from Table 1, there were many similarities of the results between the sensory panel and e-tongue. The organic oat drinks had the highest sugar and salt content, and both the panel and e-tongue confirmed this. Pascual et al. [81] found for tiger nuts that the origin of the raw material seems to be an important factor in the data values. According to the manufacturer, the barista-style product was the only one in the group of almond drinks where sugar and natural flavors were added. This explains the high sugar content in the Big 7, it was rated sweetest by the sensory panel (Figure 1B), with the e-tongue analysis showing the same results (Figure 2A). The flavors explain the high score for vanilla odor and taste. The promising results indicate that the use of an e-tongue serves as a practical and suitable tool for classifying PBMAs since the system could be used to present a fast and straightforward sensory evaluation of the basic flavors.

4.4. Comparison of Volatiles' Profile and Sensory Evaluation

Some generalizations could be made about the different product types, which were also supported by other studies. The heat treatment of the products for shelf life (ultra-high-temperature processing) is often responsible for characteristic aromas [48,82]. Almond drinks were characterized by their high content of benzaldehyde and nonanal, which were key compounds and could also impart a sweeter taste [23,47]. The presence of pyrazines in raw almonds and soybeans may be directly related to the roasting process [83,84]. Erten and Cadwallader [83] showed that the content of pyrazines depends on the roasting type (dry, oil roasted) and temperature and time.

HS-SPME could detect the high content of alcohols in soy drinks in the results shown here, as in the study by Achouri et al. [49]. In addition, typical leguminous, beany, and earthy notes may be related to the high levels of pyrazines, furans, and alkanes found in legumes [51,85].

Oats possess a unique aroma with grainy, nutty, hay-like, and grassy sensory characteristics, which were contributed by the volatile key compounds from aldehydes and ketones [86]. Consequently, oat drinks were able to show the fewest compounds in this analysis and those with the lowest percentage in qualitative similarity.

One of the main problems with the acceptance of PBMAs as cow's milk alternatives is that these products often had undesirable sensory characteristics. According to previous findings, the formation of hexanal, hexanol, and pentanal is often a result of lipid oxidation [22,23,49,51]. The previously mentioned volatile compounds induce off-flavors, such as beany and earthy flavors found in legume-based beverages [84].

The green off-flavor of soy beverages could be reduced by fermentation processes [50]. The authors significantly reduced the green odorants (hexanal, 2,4-decadienal, 2-nonenal) of a soy beverage, with hexanal falling below its odor threshold. The first two substances mentioned could also be determined in the soy drinks analyzed here. Therefore, it could be hypothesized that vanillin is used as a flavoring to hide the deficiencies of soy-based products, as they tend to taste like beany and earthy notes, sometimes with an astringent mouthfeel.

Due to the high variability, it was a challenge to generalize the sensory properties of plant-based beverages from different raw materials. Differences were evident between different product categories and within the same product type. The described characteristics of the product probably depended on the origin of the raw material and the production technology. Therefore, raw material variability should be considered in the production and development of PBMAs.

5. Conclusions

The increasing popularity and consumption of PBMAs among consumers show a shift in dietary styles in the Western world. In the present study, plant-based milk beverages, based on almond, oat and soy, from the German food market were sensory-evaluated, micronutrients were analyzed, and macronutrients' and health evaluation by the Nutri-Score were carried out. Food manufacturers could develop products that meet the sensory characteristics of PBMAs desired by consumers, i.e., with reduced off-flavors, but are not recommended from a nutritional and health perspective because of high sugar content and additives. On the other hand, products with high health value, for example, with high fiber content and no additives, come in with bitterness and astringency and are therefore not preferred by consumers. It turns out that the balance of these two important product characteristics is crucial. Plant-based products have naturally lower levels of proteins, minerals, and vitamins compared to those of cow's milk. Therefore, the content of essential amino acids and the PDCAAS in the products is lower than that in cow's milk, except in products based on legumes or in combinations of an oat-based drink with the addition of pea protein, for example. As a result, PBMAs are not nutritionally comparable or equivalent to cow's milk. However, if they are fortified with nutrients, the evaluation may be more positive. This means an adequate supply of micronutrients can be ensured if cow's milk is replaced by plant-based alternatives. Due to the wide range of products on the market, consumers need to consider the nutritional values and ingredients when choosing a product.

To encourage the consumption of plant-based milk, information on health aspects must be available to consumers. Research results published in scientific articles have to find their way to their application in relevant, everyday contexts. The identification of relevant target groups as well as communication channels is important to support a healthy diet with more plant-based and fewer animal-based foods.

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References

1. Government of Canada. Canada's Food Guide. Available online: https://food-guide.canada.ca/en/ (accessed on 1 March 2022).
2. German Nutrition Society (DGE). Guidelines of the German Nutrition Society (DGE) Status. October 2021. Available online: https://www.dge.de/wir-ueber-uns/leitbild/ (accessed on 1 March 2022).
3. Department of Nutrition at the Harvard, T.H. Chan School of Public Health. Healthy Living Guide 2021/2022. Available online: https://cdn1.sph.harvard.edu/wp-content/uploads/sites/30/2022/01/HealthyLivingGuide21-22.pdf (accessed on 1 March 2022).
4. Australian Government, National Health and Medical Research Council. Eat for Health, Australian Dietary Guidelines, Summary. Available online: https://www.eatforhealth.gov.au/ (accessed on 1 March 2022).
5. Center for Nutrition Policy and Promotion; US Department of Agriculture. Dietary Guidelines for Americans (DGA). Available online: https://www.dietaryguidelines.gov/ (accessed on 1 March 2022).
6. Poore, J.; Nemecek, T. Reducing Food's Environmental Impacts through Producers and Consumers. *Science* **2018**, *360*, 987–992. [CrossRef] [PubMed]
7. McClements, D.J.; Newman, E.; McClements, I.F. Plan—Based Milks: A Review of the Science Underpinning Their Design, Fabrication, and Performance. *Compr. Rev. Food Sci. Food Saf.* **2019**, *18*, 2047–2067. [CrossRef] [PubMed]
8. Willett, W.; Rockström, J.; Loken, B.; Springmann, M.; Lang, T.; Vermeulen, S.; Garnett, T.; Tilman, D.; DeClerck, F.; Wood, A.; et al. Food in the Anthropocene: The EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems. *Lancet* **2019**, *393*, 447–492. [CrossRef]
9. United Nations Publication. *The Sustainable Development Goals Report 2018*; United Nations: New York, NY, USA, 2018; ISBN 978-92-1-101390-0.
10. United Nations. United Nations Sustainable Developments Goals (SDGs). Goal 2: Zero Hunger. Available online: https://unric.org/en/sdg-2/ (accessed on 4 March 2022).
11. Sethi, S.; Tyagi, S.K.; Anurag, R.K. Plant-Based Milk Alternatives an Emerging Segment of Functional Beverages: A Review. *J. Food Sci. Technol.* **2016**, *53*, 3408–3423. [CrossRef]
12. Silanikove, N.; Leitner, G.; Merin, U. The Interrelationships between Lactose Intolerance and the Modern Dairy Industry: Global Perspectives in Evolutional and Historical Backgrounds. *Nutrients* **2015**, *7*, 7312–7331. [CrossRef]
13. Smart Protein Project, European Union's Horizon. Plant-Based Foods in Europe: How Big Is the Market? Smart Protein Plant-Based Food Sector Report 2020. Available online: https://smartproteinproject.eu/plant-based-food-sector-report (accessed on 4 March 2022).

14. Zühlsdorf, A.; Jürkenbeck, K.; Schulze, M.; Spiller, A. *Politicized Eater: Jugendreport zur Zukunft nachhaltiger Ernährung*; University of Göttingen: Göttingen, Germany, 2021; Volume 106.
15. Jürkenbeck, K.; Spiller, A.; Schulze, M. Climate Change Awareness of the Young Generation and Its Impact on Their Diet. *Clean. Responsible Consum.* **2021**, *3*, 100041. [CrossRef]
16. Turnwald, B.P.; Anderson, K.G.; Markus, H.R.; Crum, A.J. Nutritional Analysis of Foods and Beverages Posted in Social Media Accounts of Highly Followed Celebrities. *JAMA Netw. Open* **2022**, *5*, e2143087. [CrossRef]
17. Grand View Research. *Dairy Alternatives Market Size, Share & Trends Analysis Report by Source, by Product, by Distribution Channel, and Segment Forecasts, 2021–2028*; Grand View Research: San Francisco, CA, USA, 2021.
18. McClements, D.J. Development of Next-Generation Nutritionally Fortified Plant-Based Milk Substitutes: Structural Design Principles. *Foods* **2020**, *9*, 421. [CrossRef]
19. Paul, A.A.; Kumar, S.; Kumar, V.; Sharma, R. Milk Analog: Plant Based Alternatives to Conventional Milk, Production, Potential and Health Concerns. *Crit. Rev. Food Sci. Nutr.* **2020**, *60*, 3005–3023. [CrossRef]
20. Chalupa-Krebzdak, S.; Long, C.J.; Bohrer, B.M. Nutrient Density and Nutritional Value of Milk and Plant-Based Milk Alternatives. *Int. Dairy J.* **2018**, *87*, 84–92. [CrossRef]
21. Silva, A.R.A.; Silva, M.M.N.; Ribeiro, B.D. Health Issues and Technological Aspects of Plant-Based Alternative Milk. *Food Res. Int.* **2020**, *131*, 108972. [CrossRef]
22. Tangyu, M.; Muller, J.; Bolten, C.J.; Wittmann, C. Fermentation of Plant-Based Milk Alternatives for Improved Flavour and Nutritional Value. *Appl. Microbiol. Biotechnol.* **2019**, *103*, 9263–9275. [CrossRef]
23. Pérez-González, M.; Gallardo-Chacón, J.J.; Valencia-Flores, D.; Ferragut, V. Optimization of a Headspace SPME GC-MS Methodology for the Analysis of Processed Almond Beverages. *Food Anal. Methods* **2015**, *8*, 612–623. [CrossRef]
24. Monteiro, C.A.; Cannon, G.; Moubarac, J.-C.; Levy, R.B.; Louzada, M.L.C.; Jaime, P.C. The UN Decade of Nutrition, the NOVA Food Classification and the Trouble with Ultra-Processing. *Public Health Nutr.* **2017**, *21*, 5–17. [CrossRef] [PubMed]
25. Monteiro, C.A.; Cannon, G.; Lawrence, M.; Costa Louzada, M.L.; Pereira Machado, P. *Ultra-Processed Foods, Diet Quality, and Health Using the NOVA Classification System*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2019.
26. Regulation (EU) No 1308/2013 of the European Parliament and of the Council of 17 December 2013, Establishing a Common Organisation of the Markets in Agricultural Products and Repealing. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R1308 (accessed on 4 March 2022).
27. US Food and Drug Administration (FDA). Foods Program Guidance Under Development, Labeling of Plant-Based Milk Alternatives; Draft Guidance for Industry. Available online: https://www.fda.gov/food/guidance-documents-regulatory-information-topic-food-and-dietary-supplements/foods-program-guidance-under-development (accessed on 4 March 2022).
28. AUSNUT (AUStralian Food and NUTrient Database) 2011–13. Food Standards Australia New Zealand (FSANZ). Available online: https://data.gov.au/data/dataset/6b22884e-aab5-49d0-af5b-9d62285bd6e6 (accessed on 1 March 2022).
29. National Institute for Health and Welfare Public Health Promotion Unit. Fineli. Finnish Food Composition Database. Release Helsinki. Available online: www.fineli.fi (accessed on 1 March 2022).
30. US Department of Agriculture (USDA) FoodData Central Data. Food and Nutrient Database for Dietary Studies 2017–2018 (FNDDS 2017–2018). Available online: https://fdc.nal.usda.gov/ (accessed on 1 March 2022).
31. Max Rubner-Institute Federal Research Institute of Nutrition and Food, Bundeslebensmittelschlüssel (BLS) Version 3. Available online: https://www.blsdb.de/ (accessed on 1 March 2022).
32. Schlögl, H. Einführung des Nutri-Score in Deutschland: Erste große Studie zeigt Korrelation mit Mortalitätssenkung. *Diabetology* **2020**, *16*, 747–748. [CrossRef]
33. Santé Publique France—Conditions of Use of the "Nutri-Score" Logo, Version Dated 8 of September. Available online: https://www.santepubliquefrance.fr/content/download/150258/file/20210908_RU_International_Users_regulation_ENG.pdf (accessed on 1 March 2022).
34. Koch, M.; Busse, M.; Naumann, M.; Jákli, B.; Smit, I.; Cakmak, I.; Hermans, C.; Pawelzik, E. Differential Effects of Varied Potassium and Magnesium Nutrition on Production and Partitioning of Photoassimilates in Potato Plants. *Physiol. Plant* **2019**, *166*, 921–935. [CrossRef] [PubMed]
35. *ISO 8589:2007 + A1:2014*; Sensory Analysis—General Guidance for the Design of Test Rooms. German Version EN ISO 8589:2010 + A1; ISO: Geneva, Switzerland, 2007.
36. *ISO 8586:2012*; Sensory Analysis—General Guidelines for the Selection, Training and Monitoring of Selected Assessors and Expert Sensory Assessors. German Version EN ISO 8586; ISO: Geneva, Switzerland, 2012.
37. *DIN 10969:2018-04*; Sensory Analysis—Descriptive Analysis with Following Quality Evaluation, German Version. DIN: Berlin, Germany, 2018.
38. Grahl, S.; Palanisamy, M.; Strack, M.; Meier-Dinkel, L.; Toepfl, S.; Mörlein, D. Towards More Sustainable Meat Alternatives: How Technical Parameters Affect the Sensory Properties of Extrusion Products Derived from Soy and Algae. *J. Clean. Prod.* **2018**, *198*, 962–971. [CrossRef]
39. Lawless, H.T.; Heymann, H. *Sensory Evaluation of Food: Principles and Practices*; Food Science Text Series; Springer: New York, NY, USA, 2010; ISBN 978-1-4419-6487-8.
40. Stone, H.; Bleibaum, R.N.; Thomas, H.A. Descriptive Analysis. In *Sensory Evaluation Practices*; Elsevier: Amsterdam, The Netherlands, 2021; pp. 235–295, ISBN 978-0-12-815334-5.

41. Anon. *Alpha MOS-ASTREE e-Tongue Technical Notes*; Alpha MOS: Toulouse, France, 2020.
42. Newman, J.; Harbourne, N.; O'Riordan, D.; Jacquier, J.C.; O'Sullivan, M. Comparison of a Trained Sensory Panel and an Electronic Tongue in the Assessment of Bitter Dairy Protein Hydrolysates. *J. Food Eng.* **2014**, *128*, 127–131. [CrossRef]
43. PubChem. National Center for Biotechnology Information, US National Library of Medicine, USA. Available online: https://pubchem.ncbi.nlm.nih.gov/ (accessed on 1 March 2022).
44. Food Flavourings Database. EU Lists of Flavourings. Bruxelles, Belgium. Available online: https://webgate.ec.europa.eu/foods_system/main/?sector=FFL&auth=SANCAS (accessed on 1 March 2022).
45. FooDB. FooDB, Open-Access Food Database, Canada. Available online: https://foodb.ca/compounds (accessed on 1 March 2022).
46. Xia, Y.; Zhong, F.; Chang, Y.; Li, Y. An Aromatic Lexicon Development for Soymilks. *Int. J. Food Prop.* **2015**, *18*, 125–136. [CrossRef]
47. Manousi, N.; Zachariadis, G.A. Determination of Volatile Compounds in Nut-Based Milk Alternative Beverages by HS-SPME Prior to GC-MS Analysis. *Molecules* **2019**, *24*, 3091. [CrossRef]
48. Klein, B.; Gallardo-Chacón, J.-J.; Codina-Torrella, I.; Trujillo, A.-J.; Juan, B. Evaluation of Volatile Compounds of "Tiger Nut Beverage" (Orxata de Xufla) Headspace by Optimized Solid-Phase Micro-Extraction. *OALib J.* **2014**, *1*, e1015. [CrossRef]
49. Achouri, A.; Boye, J.; Zamani, Y. Identification of Volatile Compounds in Soymilk Using Solid-Phase Microextraction-Gas Chromatography. *Food Chem.* **2006**, *99*, 759–766. [CrossRef]
50. Nedele, A.-K.; Gross, S.; Rigling, M.; Zhang, Y. Reduction of Green Off-Flavor Compounds: Comparison of Key Odorants during Fermentation of Soy Drink with Lycoperdon Pyriforme. *Food Chem.* **2021**, *334*, 127591. [CrossRef] [PubMed]
51. Kaneko, S.; Kumazawa, K.; Nishimura, O. Studies on the Key Aroma Compounds in Soy Milk Made from Three Different Soybean Cultivars. *J. Agric. Food Chem.* **2011**, *59*, 12204–12209. [CrossRef] [PubMed]
52. Gorissen, S.H.M.; Crombag, J.J.R.; Senden, J.M.G.; Waterval, W.A.H.; Bierau, J.; Verdijk, L.B.; van Loon, L.J.C. Protein Content and Amino Acid Composition of Commercially Available Plant-Based Protein Isolates. *Amino Acids* **2018**, *50*, 1685–1695. [CrossRef]
53. Clegg, M.E.; Tarrado Ribes, A.; Reynolds, R.; Kliem, K.; Stergiadis, S. A Comparative Assessment of the Nutritional Composition of Dairy and Plant-Based Dairy Alternatives Available for Sale in the UK and the Implications for Consumers' Dietary Intakes. *Food Res. Int.* **2021**, *148*, 110586. [CrossRef]
54. Collard, K.M.; McCormick, D.P. A Nutritional Comparison of Cow's Milk and Alternative Milk Products. *Acad. Pediatr.* **2020**, *21*, 1067–1069. [CrossRef]
55. Astolfi, M.L.; Marconi, E.; Protano, C.; Canepari, S. Comparative Elemental Analysis of Dairy Milk and Plant-Based Milk Alternatives. *Food Control* **2020**, *116*, 107327. [CrossRef]
56. Vanga, S.K.; Raghavan, V. How Well Do Plant Based Alternatives Fare Nutritionally Compared to Cow's Milk? *J. Food Sci. Technol.* **2018**, *55*, 10–20. [CrossRef]
57. Singhal, S.; Baker, R.D.; Baker, S.S. A Comparison of the Nutritional Value of Cow's Milk and Nondairy Beverages. *J. Pediatr. Gastroenterol. Nutr.* **2017**, *64*, 799–805. [CrossRef]
58. Scholz-Ahrens, K.E.; Ahrens, F.; Barth, C.A. Nutritional and Health Attributes of Milk and Milk Imitations. *Eur. J. Nutr.* **2020**, *59*, 19–34. [CrossRef]
59. Aydar, E.F.; Tutuncu, S.; Ozcelik, B. Plant-Based Milk Substitutes: Bioactive Compounds, Conventional and Novel Processes, Bioavailability Studies, and Health Effects. *J. Funct. Foods* **2020**, *70*, 103975. [CrossRef]
60. Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 on Organic Production and Labeling of Organic Products and Repealing Council Regulation (EC) No 834/Current Consolidated Version: 14/11/. Available online: http://Data.Europa.Eu/Eli/Reg/2018/848/Oj (accessed on 1 March 2022).
61. Borin, J.F.; Knight, J.; Holmes, R.P.; Joshi, S.; Goldfarb, D.S.; Loeb, S. Plant-Based Milk Alternatives and Risk Factors for Kidney Stones and Chronic Kidney Disease. *J. Ren. Nutr.* **2021**, *32*, 363–365. [CrossRef]
62. Muthukumar, J.; Selvasekaran, P.; Lokanadham, M.; Chidambaram, R. Food and Food Products Associated with Food Allergy and Food Intolerance—An Overview. *Food Res. Int.* **2020**, *138*, 109780. [CrossRef] [PubMed]
63. Wensing, M.; Knulst, A.C.; Piersma, S.; O'Kane, F.; Knol, E.F.; Koppelman, S.J. Patients with Anaphylaxis to Pea Can Have Peanut Allergy Caused by Cross-Reactive IgE to Vicilin (Ara h 1). *J. Allergy Clin. Immunol.* **2003**, *111*, 420–424. [CrossRef] [PubMed]
64. Röös, E.; Garnett, T.; Watz, V.; Sjörs, C. The Role of Dairy and Plant Based Dairy Alternatives in Sustainable Diets. *Swed. Univ. Agric. Sci. Res. Platf. Future Food* **2018**, *3*, 147. Available online: https://pub.epsilon.slu.se/16016/1/roos_e_et_al_190304.pdf (accessed on 1 March 2022).
65. Grundy, M.M.-L.; Lapsley, K.; Ellis, P.R. A Review of the Impact of Processing on Nutrient Bioaccessibility and Digestion of Almonds. *Int. J. Food Sci. Technol.* **2016**, *51*, 1937–1946. [CrossRef]
66. Fardet, A.; Rock, E. Ultra-Processed Foods and Food System Sustainability: What Are the Links? *Sustainability* **2020**, *12*, 6280. [CrossRef]
67. Drewnowski, A. Perspective: Identifying Ultra-Processed Plant-Based Milk Alternatives in the USDA Branded Food Products Database. *Adv. Nutr.* **2021**, *12*, 2068–2075. [CrossRef]
68. Lane, M.M.; Davis, J.A.; Beattie, S.; Gómez-Donoso, C.; Loughman, A.; O'Neil, A.; Jacka, F.; Berk, M.; Page, R.; Marx, W.; et al. Ultraprocessed Food and Chronic Noncommunicable Diseases: A Systematic Review and Meta—Analysis of 43 Observational Studies. *Obes. Rev.* **2021**, *22*, e13146. [CrossRef]

69. Pagliai, G.; Dinu, M.; Madarena, M.P.; Bonaccio, M.; Iacoviello, L.; Sofi, F. Consumption of Ultra-Processed Foods and Health Status: A Systematic Review and Meta-Analysis. *Br. J. Nutr.* **2021**, *125*, 308–318. [CrossRef]
70. Matos, R.A.; Adams, M.; Sabaté, J. Review: The Consumption of Ultra-Processed Foods and Non-Communicable Diseases in Latin America. *Front. Nutr.* **2021**, *8*, 622714. [CrossRef] [PubMed]
71. Romero Ferreiro, C.; Lora Pablos, D.; Gómez de la Cámara, A. Two Dimensions of Nutritional Value: Nutri-Score and NOVA. *Nutrients* **2021**, *13*, 2783. [CrossRef] [PubMed]
72. Sosulski, F.W.; Chakraborty, P.; Humbert, E.S. Legume-Based Imitation and Blended Milk Products. *Can. Inst. Food Sci. Technol. J.* **1978**, *11*, 117–123. [CrossRef]
73. Chambers, E.; Jenkins, A.; Mcguire, B.H. Flavor propreties of plain soymilk. *J. Sens. Stud.* **2006**, *21*, 165–179. [CrossRef]
74. Hoppu, U.; Puputti, S.; Sandell, M. Factors Related to Sensory Properties and Consumer Acceptance of Vegetables. *Crit. Rev. Food Sci. Nutr.* **2021**, *61*, 1751–1761. [CrossRef]
75. Bach, V.; Kidmose, U.; Kristensen, H.L.; Edelenbos, M. Eating Quality of Carrots (*Daucus Carota* L.) Grown in One Conventional and Three Organic Cropping Systems over Three Years. *J. Agric. Food Chem.* **2015**, *63*, 9803–9811. [CrossRef]
76. Janssen, M. Determinants of Organic Food Purchases: Evidence from Household Panel Data. *Food Qual. Prefer.* **2018**, *68*, 19–28. [CrossRef]
77. Tobin, R.; Moane, S.; Larkin, T. Sensory Evaluation of Organic and Conventional Fruits and Vegetables Available to Irish Consumers. *Int. J. Food Sci. Technol.* **2013**, *48*, 157–162. [CrossRef]
78. N'Kouka, K.D.; Klein, B.P.; Lee, S.-Y. Developing a Lexicon for Descriptive Analysis of Soymilks. *J. Food Sci.* **2006**, *69*, 259–263. [CrossRef]
79. Torres-Penaranda, A.V.; Reitmeier, C.A. Sensory Descriptive Analysis of Soymilk. *J. Food Sci.* **2001**, *66*, 352–356. [CrossRef]
80. Yang, A.; Smyth, H.; Chaliha, M.; James, A. Sensory Quality of Soymilk and Tofu from Soybeans Lacking Lipoxygenases. *Food Sci. Nutr.* **2016**, *4*, 207–215. [CrossRef] [PubMed]
81. Pascual, L.; Gras, M.; Vidal-Brotóns, D.; Alcañiz, M.; Martínez-Máñez, R.; Ros-Lis, J.V. A Voltammetric E-Tongue Tool for the Emulation of the Sensorial Analysis and the Discrimination of Vegetal Milks. *Sens. Actuators B Chem.* **2018**, *270*, 231–238. [CrossRef]
82. Toro-Funes, N.; Bosch-Fusté, J.; Veciana-Nogués, M.T.; Vidal-Carou, M.C. Effect of Ultra High Pressure Homogenization Treatment on the Bioactive Compounds of Soya Milk. *Food Chem.* **2014**, *152*, 597–602. [CrossRef]
83. Erten, E.S.; Cadwallader, K.R. Identification of Predominant Aroma Components of Raw, Dry Roasted and Oil Roasted Almonds. *Food Chem.* **2017**, *217*, 244–253. [CrossRef]
84. Alasalvar, C.; Shahidi, F.; Cadwallader, K.R. Comparison of Natural and Roasted Turkish Tombul Hazelnut (*Corylus Avellana* L.) Volatiles and Flavor by DHA/GC/MS and Descriptive Sensory Analysis. *J. Agric. Food Chem.* **2003**, *51*, 5067–5072. [CrossRef]
85. El Youssef, C.; Bonnarme, P.; Fraud, S.; Péron, A.-C.; Helinck, S.; Landaud, S. Sensory Improvement of a Pea Protein-Based Product Using Microbial Co-Cultures of Lactic Acid Bacteria and Yeasts. *Foods* **2020**, *9*, 349. [CrossRef]
86. McGorrin, R.J. Key Aroma Compounds in Oats and Oat Cereals. *J. Agric. Food Chem.* **2019**, *67*, 13778–13789. [CrossRef]