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Review

Literature-Based Inventory of Chemical Substance Concentrations Measured in Organic Food Consumed in Europe

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Abstract: Populations are exposed daily to numerous environmental pollutants, particularly through food. To address environmental issues, many agricultural production methods have been developed, including organic farming. To date, there is no exhaustive inventory of the contamination of organic foods as there is for conventional foods. The main objective of this work was to construct a growing and updatable database on chemical substances and their levels in organic foods consumed in Europe. To this end, a literature search was conducted, resulting in a total of 1207 concentration values from 823 food–substances pairs involving 166 food matrices and 209 chemical substances, among which 95% were not authorized in organic farming and 80% were pesticides. The most encountered substance groups are "inorganic contaminants" and "organophosphate", and the most studied food groups are "fruit used as fruit" and "Cereals and cereal primary derivatives". Further studies are needed to continue updating the database with robust and comprehensive data on organic food contamination. This database could be used to study the health risks associated with these contaminants.

Keywords: organic food; pollutants; database; contaminants; residues; metals; persistent organic pollutants; pesticides

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1. Introduction

The concept of the exposome is now defined as the cumulative measure of environmental exposures (positive or negative) and associated biological responses to which living things are exposed to from conception and throughout their lives that may affect their health. It includes environmental exposures to chemical, biological, and physical agents, as well as lifestyle, socioeconomic and cultural determinants, and psychosocial context [1–5]. Due to the contamination of the food chain by a multitude of environmental pollutants [6], food is a major source of exposure for humans and, therefore, a significant part of their chemical exposome. On the other hand, in order to meet the food needs of an ever-growing world population while responding to the challenges of sustainable development, several agricultural production methods have been developed and coexist, such as organic, biodynamic or sustainable agriculture [7–9]. As far as organic farming is concerned, the European Union (EU) has seen a steady increase from 14.7 million hectares in 2020 [10] up to 16.9 million hectares in 2022, i.e., 10.4% of the total agricultural area, with France holding the largest organic production area in the EU, with 2.9 million hectares, in 2022 [11].

Organic farming is subject to strict regulations. In the EU, organic farming and production rules are enforced by Regulation (EC) 2018/848 [12]. This regulation includes, in particular, a ban on the use of chemically synthesized plant protection products, the use of specific natural fertilizers and natural pest control methods, the exclusive use of organically produced seeds while avoiding GMOs, the recycling of organic matter, the use of crop rotation, a preference for plant varieties adapted to local conditions, a particular attention to animal welfare, and the limited use of medicinal products for therapeutic purposes ((EC)

2018/848). In addition, these regulations specify extensive controls on labelling and provide a list of natural substances authorized in organic farming, such as azadirachtin derived from the *Azadirachta indica* (neem trees seeds), Spinosad produced by *Saccharopolyspora spinosa* (soil bacterium), copper, and pyrethroids derived from *Chrysanthemum indicum* (Chrysanthemum) ((EC) 2021/1165).

Despite all the regulations, there are also ubiquitous environmental contaminations over which we have no particular control in organic products, including heavy metals [13,14]; persistent organic pollutants (POP) such as dioxins; polychlorobiphenyls (PCBs) [15–17]; inorganic components such as cadmium, lead, arsenic [14,18]; and brominated compounds [16], but also pesticides authorized in conventional agriculture that can circulate in the biosphere and contaminate organic products [19,20]. For example, in Almeida-González et al., medians for the sum of organochlorine (OC) pesticides were found to be three times lower in organic cheese (14.44 ng/g fat vs. 42.73 ng/g fat in conventional cheese, $p = 0.001$), while PCBs were found to be 2.4 times higher in the organic batch (22.55 ng/g fat vs. 9.57 ng/g fat in the conventional batch, $p = 0.074$) [15]. Significantly higher levels of dioxins and PCBs were also found in organic pork and chicken, up to three times higher for the 6 non-dioxin like PCBs in pork [16]. Regarding cadmium, some studies show significantly higher levels in certain vegetables compared to conventional ones (up to two times higher in spinach and carrots), while they are around 1.2 times lower in food matrices like potatoes and lettuce [14,18]. In terms of exposure levels, a study of 13 adults showed that switching to a diet of 80% organic foods for one week significantly reduced the population's exposure to organophosphate pesticides compared to people eating a diet of only conventionally farmed foods [21]. Similar studies in groups of primary-school-age children have also shown that median urinary concentrations of metabolites of some pesticides were significantly reduced immediately after the introduction of organic foods [22–24].

In 2011, the European Food Safety Authority (EFSA), the Food and Agriculture Organization of the United Nations (FAO), and the World Health Organization (WHO) jointly published a guidance document on a harmonized approach to the assessment of dietary exposure to chemicals, known as the Total Diet Study (TDS) [25]. This methodology is based on the analysis of chemical substances present in foods combined with data on food consumption and, therefore, requires data on food contamination. However, the databases available in the literature or from health agencies, although very extensive in terms of the number of substances studied in foods from conventional agriculture, contain little or no data on the contamination of foods from organic farming. This scarcity is evident in the latest EFSA report, in which organic foods represent only 6.5% of all the samples tested [26]. At a national level, the database of the Chemical and Veterinary Investigation Offices (CVUA) in Stuttgart, Germany, provides concentrations for pesticides in organic foods [27], which were included in the EFSA report. In France, as part of its studies on total diet, the French Agency for Food, Environmental, and Occupational Health and Safety (ANSES) offers a database on the contamination of foods as consumed by the population. It covers 455 chemical substances (pesticides, dioxins, PCBs, heavy metals, etc.) and 212 food matrices but does not report any specific data on organically produced foods [28].

The aim of this study was to build a growing and updatable database containing already available data in the literature on the chemical content of organic food matrices present on the EU market. To this end, an extensive literature search was carried out, the stages of research and selection of articles of which are described in detail in the Section 2. This paper presents a qualitative description of the constructed database in terms of content (food matrices, chemicals, matrix–chemical substance pairs) and provides a comprehensive overview of what has already been studied in the literature on chemicals contained in organic foods present in the European market.

2. Methods

2.1. Literature Search and Identification of Articles of Interest

An extensive literature search was carried out from June 10 to 15, 2021 in four electronic databases: PubMed, Web of Science (WoS), Embase, and Agricola. The phrase "contaminants and residues in organic food" was used for the search in all databases except for PubMed where the following medical subject headings (MeSH) were used: pesticide* OR contaminant* OR pollutant* OR chemical* OR herbicide* OR fertilizer* OR fungicide* OR insecticides OR metals* OR antibiotics*) AND (residues OR contamination* OR exposure*) AND organic* AND (food* OR product*). All articles published from 1 January 2000 to 15 June 2021 in PubMed and from inception to 15 June 2021 in other databases were included in the analysis. The manipulation, sorting, and merging of articles extracted from the databases were performed on Zotero v5.0.96.3 (https://zotero.org) and the results were exported to an Excel sheet. In addition to the literature search, EFSA reports were targeted. Indeed, EFSA is the major source of data and regulations related to foods in the EU Region. Only reports on pesticide residues in foods dealing with chemicals in organic foods from 2008 to 2021 were included in the study.

2.2. Study Selection and Eligibility Criteria

The articles were selected in four steps using criteria based on the language, title, abstract, and data availability (see Table S1 in Supplementary Materials). Briefly, the selected studies had to be written either in English or in French and had to deal with organic foods and any chemical substances they might contain. Finally, the article must contain values for the concentration of chemical substances in organic food from EU markets.

All the articles that did not meet the criteria were excluded; the remainder were scanned for concentration values. Articles that did not have any data were examined to see if they contained supplemental material for concentration records; otherwise, they were excluded. Likewise, articles with concentration values that did not correspond to food matrices from the EU market were also excluded, as our aim is to create an inventory on chemical substances in organic food in the EU region.

2.3. Data Extraction

The concentration values (mean ± SD and/or distribution as appropriate) were grouped with the corresponding food matrix and chemical substance in an Excel table. The number of matrices tested, the number of positive samples, the limits of quantification (LOQ: the lowest concentration of an analyte in a sample that can be reliably quantified), the limits of detection (LOD: the lowest concentration of an analyte in a sample that can be reliably detected), and the minimum and maximum values were added to the table whenever they were reported in the studies. Additional columns were added, including country of origin, continent of origin, level 2 nomenclature foodEx2 group to which the matrix belongs (FX-L2, Tables S2 and S3), code of the foodEx2 group (code_FX in Table S3), food matrices, chemical substances, substance groups, general groups, supplementary information, pair frequency, LOD/LOQ units, measurement types, chemical types, and references. Table 1 describes the columns in the database table, and Tables S2 and S3 detail the elements found in each column.

Table 1. Description of columns in the database table.

Countries of Origin	Country of Origin of the Corresponding Matrix
COO by continents	Continent in which the country of origin is
FX_L2	The foodEx2 group from level 2 nomenclature to which belongs the matrix
Code_FX	The code of the foodEx2 group
Food matrices	The food item
Chemical substances	The chemical substance detected

Table 1. *Cont.*

Countries of Origin	Country of Origin of the Corresponding Matrix
Substance groups	The chemical family group of the substance
General groups	The largest category to which belong this chemical substance
Complementary information	The use (for pesticides) or details on the chemical substance
Couple frequency	The number of times the couple (matrix, chemical substance) occurs in the database
Number of samples tested	The number of samples tested of this food matrix
Number of positive samples	The number of samples in which chemical substances were detected
Concentrations	The concentration value
Measurement units	The unit of the concentration value
SD	The standard deviation of the concentration value
Min	The minimum concentration value when values are expressed in ranges
Max	The maximum concentration value when values are expressed in ranges
LOD	The limit of detection
LOQ	The limit of quantification
LOD/LOD units	The unit of the LOD and/or LOQ values
Measurement types	The type of measurement: mean, median, range, single value, or ND when undetermined
Chemical types	The type of chemical: residue (authorized substance in organic food), contaminant (non-authorized substance in organic food or environmental pollution)
References	Data source

2.4. Data Analysis

2.4.1. Food Matrices and Chemical Substance Classifications

To facilitate the analysis of the database, the organic food matrices and the chemical substances were aggregated into broader groups, allowing a description on a wider scale of what has been more represented in the database table. For each food matrix, a group nomenclature and a code were assigned following the food classification and description system FoodEx2 L2 [29]. For the chemical substances, substance groups (the chemical family group of the substance), general groups (the largest category to which belong this chemical substance) and complementary information were assigned for each substance. For the pesticides, the classifications were based on the Pesticide Properties DataBase (PPDB) [30].

2.4.2. The Scientific Interest

The scientific interest (SI) is used to assess the importance of a variable (food matrix, chemical substance, matrix–chemical substance pair) based on the number of values in the database. The variables were then classified as high SI, medium SI, or low SI depending on the number of concentration values related to them in the database. A variable is considered high SI when twenty or more concentration values are reported, medium SI when the number of concentration values lies between ten (included) and twenty (excluded), and low SI for the number of concentration values less than ten. As defined, SI < 10 represents variables of low importance and that are rarely studied, while SI $\geq$ 20 corresponds to variables more frequently studied. This SI is a simplified version of the one defined by Rieutort et al. that served as the primary inspiration for the classification [31].

2.4.3. Data Processing and Analysis

The database was implemented using an Excel spreadsheet. All statistical processing and analyses were performed using Excel (Version 16.78) and R software (Version 2023.06.1+524).

3. Results and Discussion

3.1. Identification of Concentration Values of Chemical Substances in Organic Food

The literature search resulted in a total of 15,455 articles out of which 22 articles were considered after the exclusion of duplicate reports and those not meeting the selection

criteria (Table S1) based on language, title, abstract, the database availability, and the region of consumption. Furthermore, 10 articles from the EFSA database were added, including databases on concentration values of chemical substances in organic food, resulting in 32 articles in total (Figure 1). In total, 32 studies (22 scientific articles and 10 EFSA database) out of 12,500 articles met the inclusion criteria, i.e., 0.25% of inclusion. Such a small proportion of results indicates that the presence of chemical substances in organic food matrices is not that much studied in the literature, especially in the EU region.

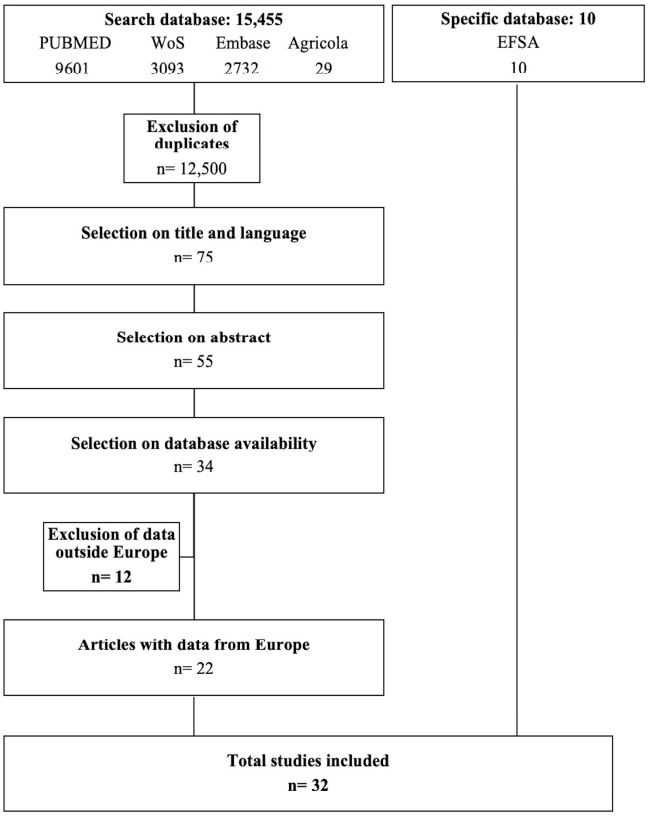


Figure 1. Selection of studies with concentration values for chemical substances in organic food matrices consumed in Europe.

These studies resulted in a database table of 1207 concentration values for chemical substances in organic food consumed in EU. The limitations in the reported data from the literature were that the number of analyzed samples, as well as limits of detection and quantification, are not always indicated in studies. In addition, some concentrations are reported by ranges, others may be means, medians, a single value, or sometimes not specified at all. The database table "Pollutants in Organic Food consumed in Europe (POFE)" can be found at Choueiri et al. [32].

3.2. Descriptive Analysis of the Database

3.2.1. Description of the Database Table

A total of 166 matrices and 209 chemical substances were found, resulting in 823 couples (matrix, substance). All food matrices were retrieved from the EU market, but they originated from 63 different EU and non-EU countries worldwide. The food matrices were grouped into 34 different FoodEx 2 level 2 categories. The chemical substances, also grouped into larger categories, resulted in 74 substance groups and 6 general groups (pesticides, inorganic contaminants, minerals, dioxins, PCBs, and brominated flame retardants). Concerning the data sources, 58% of concentration values were from EFSA and 48% from the rest of the data sources (non-EFSA). Figure 2 shows the summary of the overall distribution of the parameters in the database table.

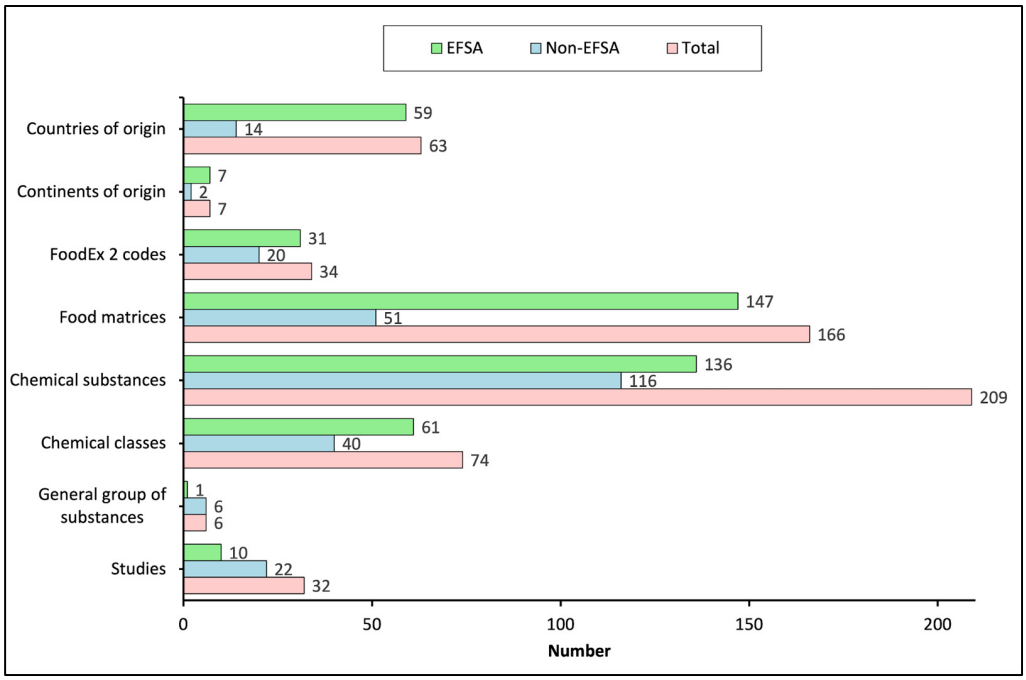


Figure 2. Distribution of the variables in POFE. Quoted numbers to the histogram bars correspond to the total number of distinct variables. The non-EFSA columns represent all the data of studies from PUBMED, WoS, Embase, and Agricola.

3.2.2. Description of Food Matrices

The number of values varied among the organic food matrices: 132 food matrices (79.5% of the total matrices) were of low SI (have less than 10 concentration values in the database), while 21 were of medium SI (have between 10 and 20 values in the database) and 13 were of high SI (have more than 20 values in the database) (Figure 3A). The food matrices "Baby food other than processed cereal-based foods" and "Tea (green, black)" are the most represented with a number of values of 80 (from 6 studies) and 76 (from 8 studies), respectively (Figure 3B).

In the case of baby food, the high SI can be related to the fact that this food matrix is intended for a particularly vulnerable population [33]. As for tea, this could be explained by the fact that this food matrix is at the top of the list of organic matrices imported into many EU countries, including Estonia, France, Spain, Czech Republic, Poland, Slovakia, and Sweden [34]. In addition, special attention should be paid to wheat and wheat products (wheat (undefined form), wheat flour, and wheat grain), which were included in the high SI category (Figure 3B). This focus in the literature may originate from the fact that cereals are the main contributor to the global food supply, accounting for more than half of total human caloric requirements, and the EU (with 450 million inhabitants) is the second largest consumer of wheat in the world after China [35].

On the other hand, several organic matrices were less represented in terms of number of values but have been investigated in more studies. For example, "wheat" and "tomato" have 53 and 40 values from 12 out of 32 articles, respectively. This highlights the heterogeneity of the data in the literature, with some matrices having been studied more than others, and the need for more quantitative studies to understand chemical levels and contents of less-studied organic matrices.

Furthermore, there was a variability in the association of organic food matrices with chemical substances: 48% of food matrices were investigated for a single chemical, while the rest were studied for multiple chemicals. Figure 4 shows the 18 OFs with contamination values for 10 or more different chemical substances. For example, "rye grain" has contamination values for 38 different chemical substances, "poultry meat" has contamination

values for 10 different chemical substances (Figure 4), whereas "pear" has values only for one chemical substance (not shown in Figure 4).

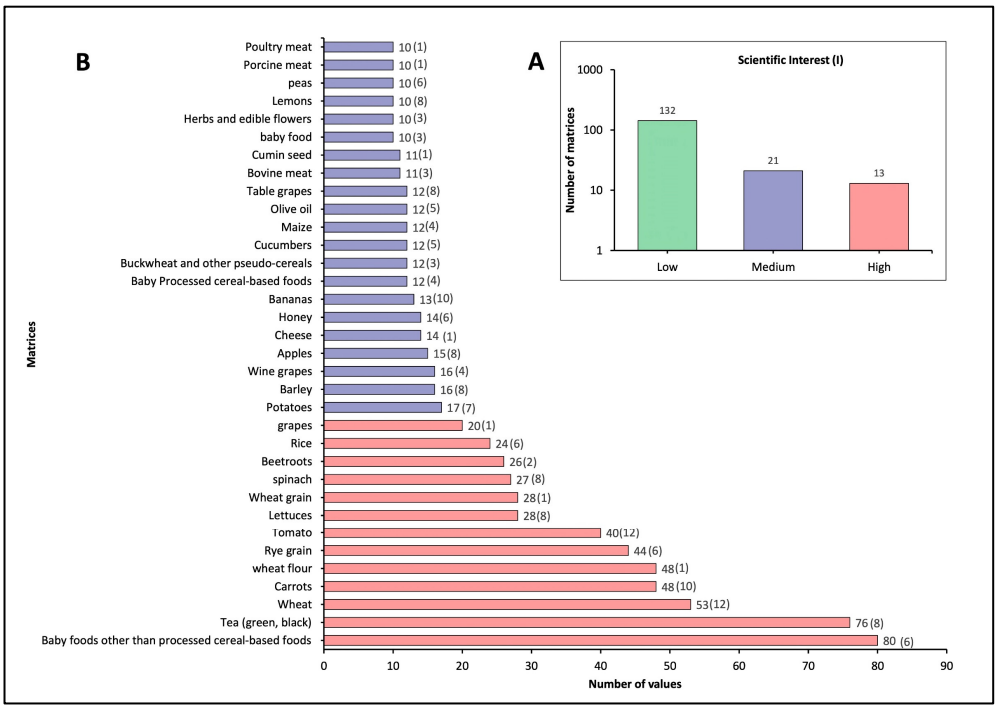


Figure 3. (**A**): Distribution of organic food matrices in low, medium, and high scientific interest (SI). Low, medium, and high SI correspond to matrices with number of values <10, ≥10 and <20, and ≥20, respectively. (**B**): Matrices ranked by number of values (number of studies) for matrices with medium (purple) and high (pink) SI.

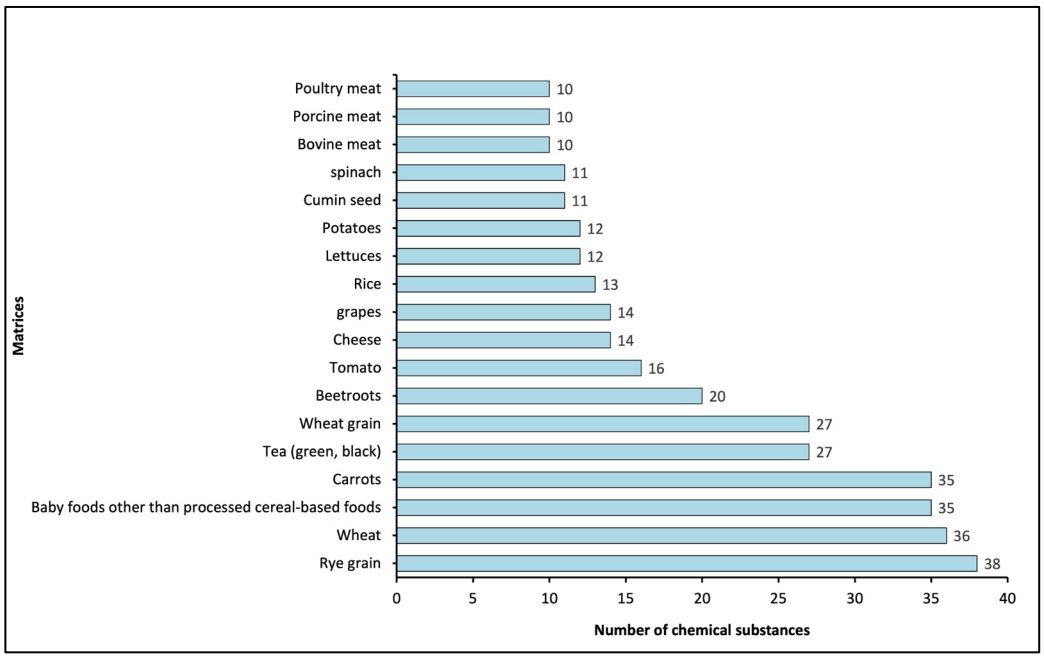


Figure 4. Organic food matrices with 10 or more quantified distinct chemical substances.

3.2.3. Description of Chemical Substances

The current POFE database includes in total 209 different chemical substances. The number of values for each substance is distributed as follows: 180 chemical substances (86% of the total substances) are of low SI, 19 (9%) are of medium SI, and 10 (4.8%) are of high SI (Figure 5A). "Chlorate" and "Fosetyl-Al" were the most studied, with 117 and 76 values from 4 and 6 studies, respectively. Other substances with medium SI like "Imidacloprid", "Acetamiprid", and "boscalid" (with 19, 17 and 13 values, respectively) are considered by a higher number of studies, 11 for each of them out of 32 articles (Figure 5B).

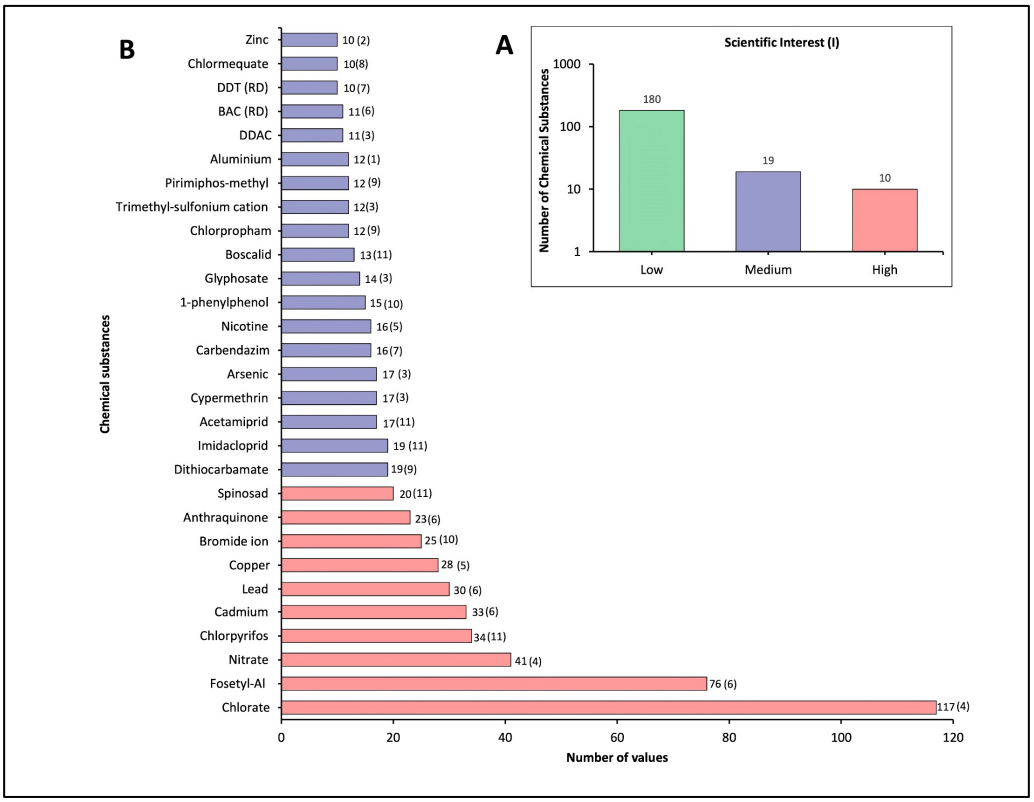


Figure 5. (**A**): Distribution of chemical substances in low, medium, and high scientific interest (SI). Low, medium, and high SI correspond to chemical substances with number of values <10, ≥10 and <20, and ≥20, respectively. (**B**): Chemical substances ranked by number of values (number of studies) for substances with medium (purple) and high (pink) SI.

Similarly to the organic food matrices, there was a variability in the association of chemical substances and organic food matrices: only 58% of the substances studied were analyzed in more than one organic food matrix. Figure 6 identifies the chemical substances detected in at least 10 different organic matrices. Chlorate is the chemical substance that was analyzed in the most different organic foods with 52 different matrices analyzed (Figure 6).

The majority of the chemical substances were pesticides (80%), while the rest were inorganic contaminants (9%), minerals (5%), PCBs (2%), dioxins (4%), and brominated flame retardants (0.25%). This is because the production of organic food prohibits the use of synthetic pesticides, and therefore, there is an interest in testing these substances for possible contamination. In addition, only 5% of the pesticides detected were substances authorized for use in organic food, including spinosad, azadirachtin, pyrethrins, and copper. This underlines the lack of studies on the presence of authorized substances in organic food and the need to study their levels in organic food more closely, especially as the natural origin of these substances does not exempt them from a potentially toxic impact on human health [36].

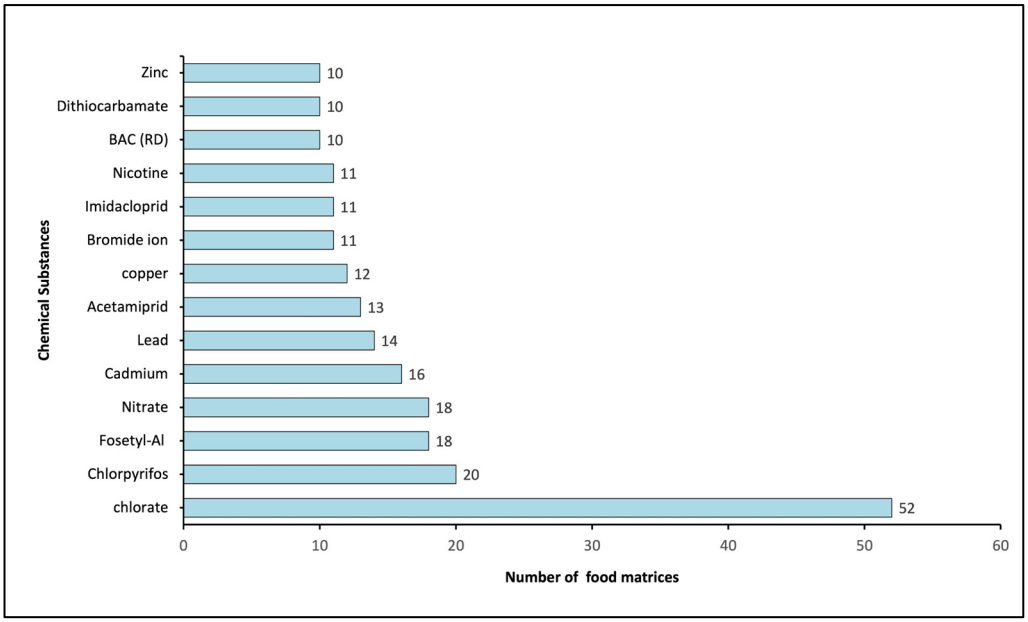


Figure 6. Chemical substances detected in at least 10 distinct organic food matrices.

After pesticides, inorganic contaminants (9% of values) have the most values in the database, with cadmium and lead having the most values (33 and 30 values, respectively) (Figure 5A). This may be because lead and cadmium are among the 10 chemical substances of greatest concern for public health [37,38]. As far as PCBs, dioxins, minerals, and brominated compounds are concerned, the fact that they receive little attention in the literature on organic food does not mean that they are any less of a health concern or that their presence in organic food is any less likely. For example, PCBs are ubiquitous and long-lasting environmental contaminants that have been shown to be present in higher concentrations in organic food matrices than in conventional matrices, particularly in meat [16] or other fatty matrices such as cheese [15].

In addition, several European TDS have shown that the risk associated with the presence of a number of these substances in food cannot be excluded. The French and UK TDS concluded that certain inorganic contaminants, in particular lead, cadmium and inorganic arsenic, posed health problems [39,40]. The French TDS also identified other substances of concern, including PCBs and dioxins, and certain minerals such as copper and aluminum [39,41]. It is, therefore, important to further assess the presence of these substances in organic foods to investigate their effects on human exposure levels.

3.2.4. Description of Couples (Matrix, Chemical Substance)

While POFE consists of 823 different couples, only 8 couples have more than 10 values (medium SI) (Figure 7A) and only one single couple "Baby food other than processed cereal-based foods, Fosetyl-Al" was ranked as high SI with 66 values from 6 different studies (Figure 7B). The couples "Baby foods other than processed cereal-based foods, Fosetyl-Al" and "Tea (green, black), Anthraquinone" were the most studied in terms of number of articles (6 articles for each). Specifically, 88.4% (783/823) of couples were from a single study.

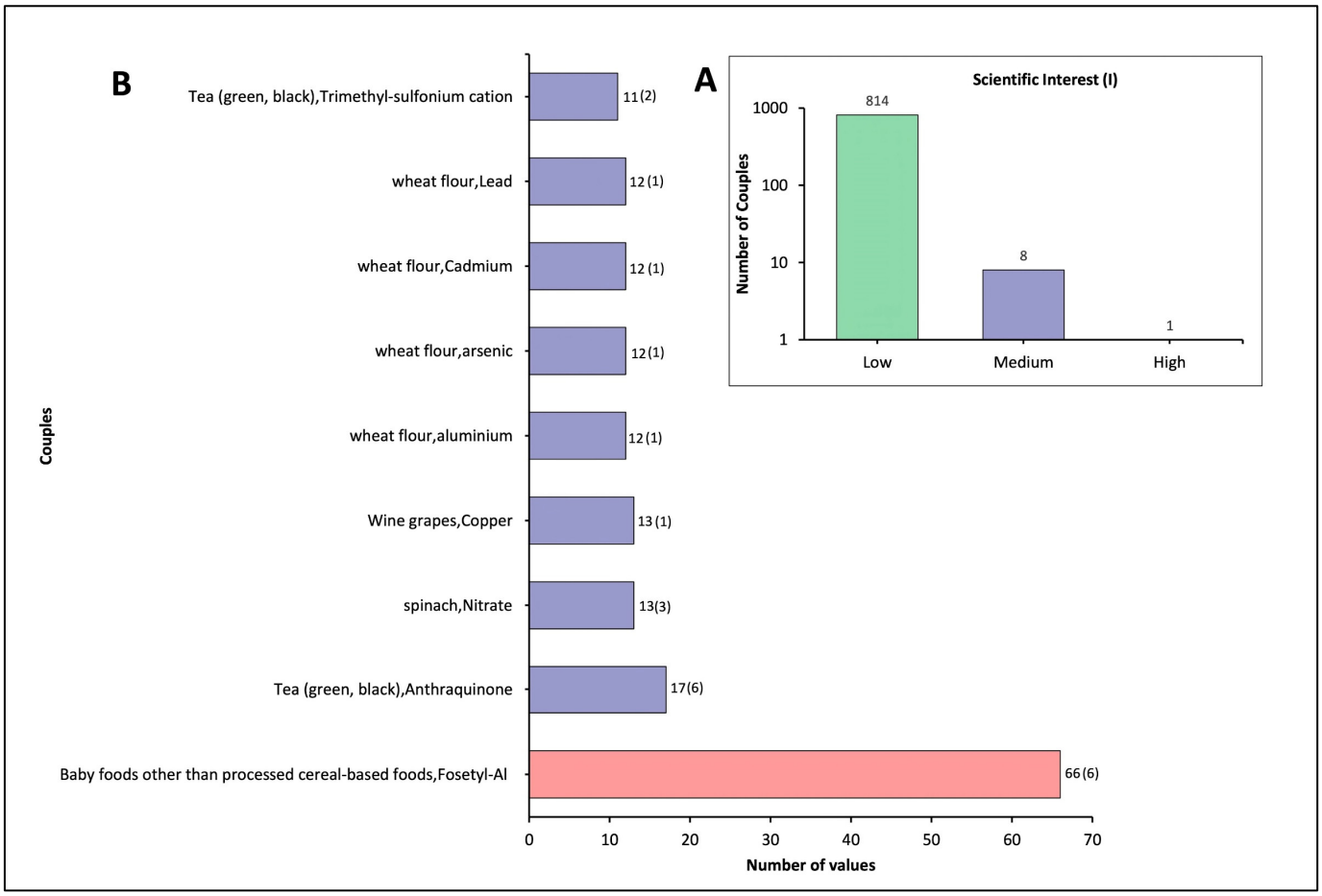


Figure 7. (**A**): Distribution of couples (matrix, chemical substance) in low, medium, and high scientific interest (SI). Low, medium, and high SI correspond to chemical substances with number of values <10, ≥10 and <20, and ≥20, respectively. (**B**): Couples ranked by number of values (number of studies) with medium (purple) and high (pink) SI.

3.2.5. Description of Database by FoodEx Groups

For a comprehensive overview, the 166 matrices were grouped according to the FoodEx2 group nomenclature, thus resulting in 34 FoodEx2 groups. Table S3 in the Supplementary Materials lists the food matrices in FoodEx2 groups. The distribution in terms of SI was as follows: 12, 10, and 12 FoodEx groups were classified as low, medium, and high, respectively. The groups with the most data (high SI) include "Fruit used as fruit", "Ready-to-eat meal for infants and young children", "Cereals and cereal primary derivatives", "Herbs and edible flowers", "Legumes", "Root and tuber vegetables (excluding starchy- and sugar-)", "Mammals and birds meat", "Nuts, oilseeds and oilfruits", "Leafy vegetables", "Coffee, cocoa, tea and herbal ingredients", "Fruiting vegetables", and "Spices".

Figure 8 represents the distribution of the FoodEx groups according to the total number of chemicals substances studied in these groups. The three groups with the highest number of chemical substances were "Cereals and Primary Cereal Derivatives" with 83 substances (78 contaminants and 5 residues), followed by "Fruit used as fruit" with 65 substances (63 contaminants and 2 residues) and "Root and tuber vegetables (excluding starch and sugar)" with 42 substances (42 contaminants and 0 residue) (Figure 8). The groups "infant and follow-on formulae", "savoury extracts and sauce ingredients", and "sprouts, shoots and similar" comprised only 1 chemical substance, i.e., involving 0.4% of all chemical substances in the database (Figure 8).

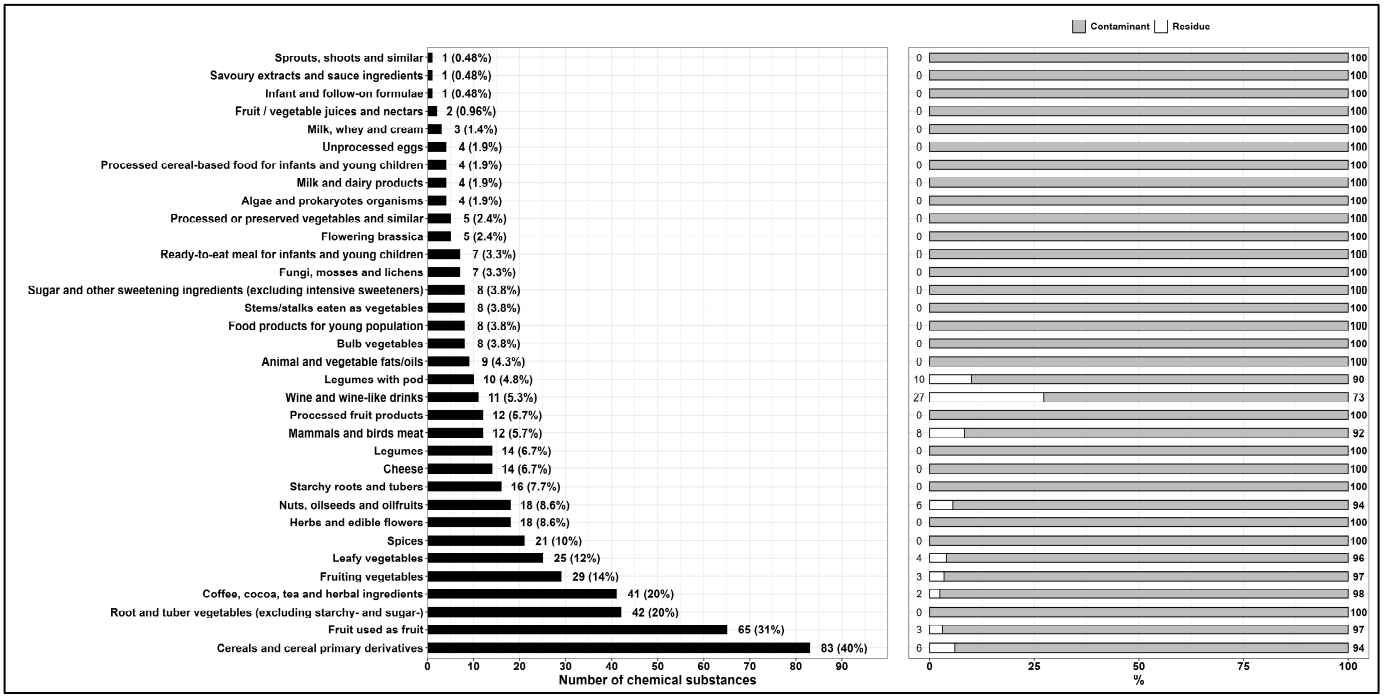


Figure 8. FoodEx groups ranked by number of chemical substances. (**Left panel**): black horizontal bars with quoted numbers standing for the total number of chemical substances (% of the total chemical substances). (**Right panel**): Total number of chemical substances subdivided into percentage of "Contaminants" (gray horizontal bars) for the number of contaminants, i.e., not allowed in organic agriculture (% of the total contaminants at the right vertical axis), and "Residues" (light horizontal bars) for the number of residues, i.e., allowed in organic agriculture (% of the total residues at the left of vertical axis).

3.2.6. Description of Substance Group per FoodEx Group

Likewise, chemical substances were classified according to a generic group "substance groups", as described in Table S4 in the Supplementary Materials. Figure 9 shows the 74 substance groups obtained. The groups with the most values were organophosphates (191), inorganic contaminants (132), chlorates (117), organochlorine (94), and PCBs (70) (column "Total" in Figure 9).

Figure 9 also provides the number of concentration values for pairs substance group–FoodEx group in the database. With a total of 311 distinct pairs (chemical group, FoodEx2 group) in POFE, only 16 and 10 pairs were of medium and high SI, respectively. Organophosphates in 3 FoodEx groups, "Ready-to-eat meal for infants and young children" (67), "Cereals and cereal primary derivatives" (28), and "fruit used as fruit" (25), along with inorganic contaminants in "Cereals and cereal primary derivatives" (72), organochlorines and PCBs in the two groups "Cereals and cereal primary derivatives" (27 and 30, respectively) and "Root and tuber vegetables (excluding starchy- and sugar-)" (30 and 28, respectively), and nitrates in "Leafy vegetables" (29) were the pairs with the highest number of values in the table.

A figure similar to Figure 9 showing the number of studies for the different pairs is presented in Figure S1 in the Supplementary Materials. Inorganic contaminants and organophosphates were the most considered by the literature in terms of number of studies (17 studies each). Organophosphates in "Fruit used as fruit" were the most considered (11 studies), followed by organophosphates in "Cereals and cereal primary derivatives" (10 studies).

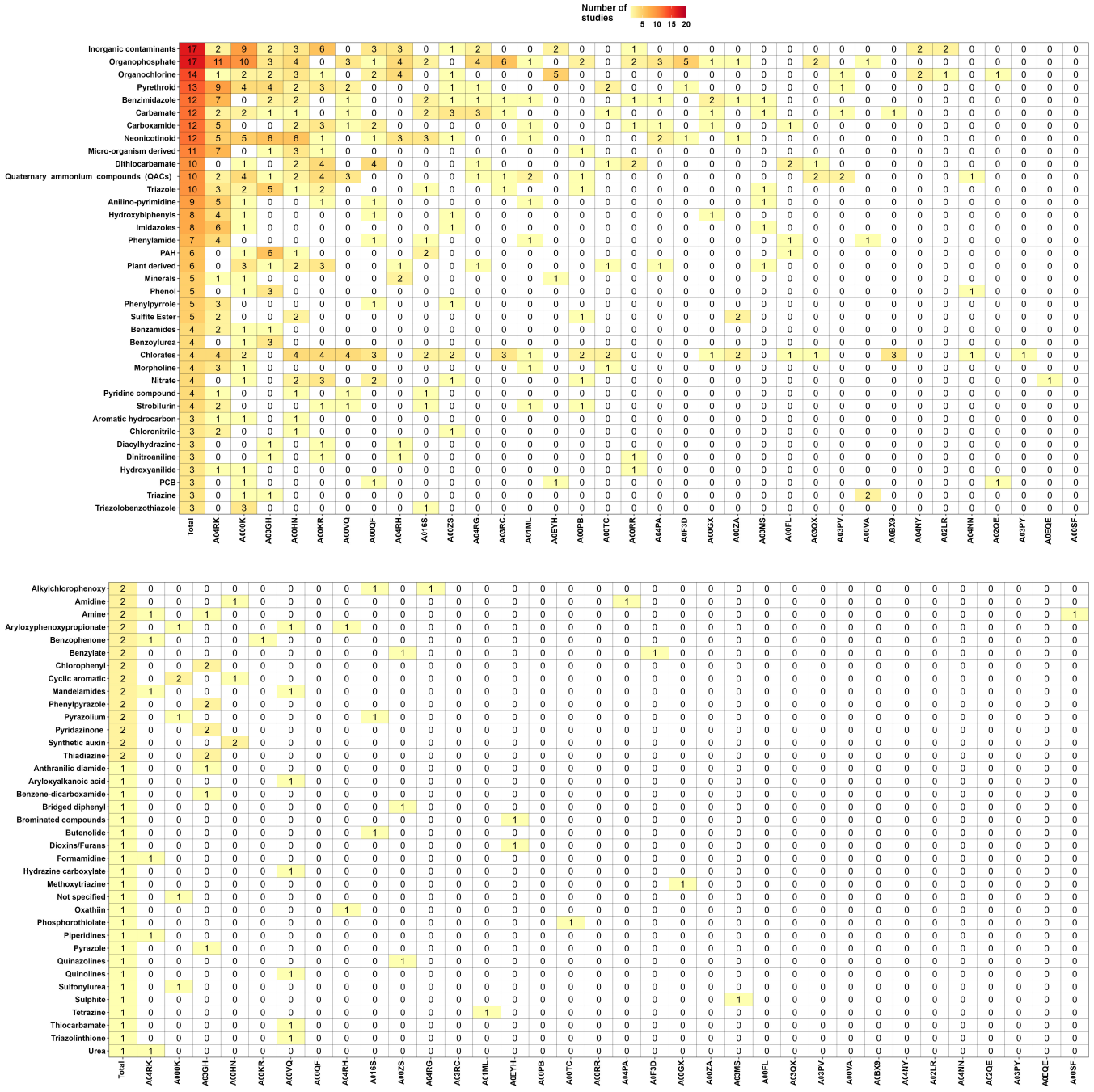


Figure 9. Matrix table of substance groups (rows) versus FoodEx group codes (columns). Numbers in the cells at the intersection represent the number of concentration values for the pair substance group–FoodEx group. Codes of FoodEx groups are described in Figure 10.

Wine and wine-like drinks	A03MS
Unprocessed eggs	A04NY
Unknown	Unknown
Sugar and other sweetening ingredients (excluding intensive sweeteners)	A04PA
Stems/stalks eaten as vegetables	A00RR
Stems stalks eaten as vegetables	A00RR
Starchy roots and tubers	A00ZS
Sprouts, shoots and similar	A00SF
Spices	A016S
Savoury extracts and sauce ingredients	A0EQE
Root and tuber vegetables (excluding starchy- and sugar-)	A00QF
Ready-to-eat meal for infants and young children	A03RC
Processed or preserved vegetables and similar	A00ZA
Processed fruit products	A01ML
Processed cereal-based food for infants and young children	A03QX
Nuts, oilseeds and oilfruits	A04RH
Milk, whey and cream	A04NN
Milk and dairy products	A02LR
Mammals and birds meat	A0EYH
Legumes with pod	A00PB
Legumes	A04RG
Leafy vegetables	A00KR
Infant and follow-on formulae	A03PY
Herbs and edible flowers	A00VQ
Fungi, mosses and lichens	A00TC
Fruiting vegetables	A00HN
Fruit used as fruit	A04RK
Fruit / vegetable juices and nectars	A0BX9
Food products for young population	A03PV
Flowering brassica	A00FL
Coffee, cocoa, tea and herbal ingredients	A03GH
Cheese	A02QE
Cereals and cereal primary derivatives	A000K
Bulb vegetables	A00GX
Animal and vegetable fats/oils	A0F3D
Algae and prokaryotes organisms	A00VA
Foodex group	**code**

Figure 10. Codes of FoodEx groups used in Figure 9.

3.3. Summary

Organic farming is an environmentally friendly agricultural system that favors natural practices, notably avoiding the use of synthetic chemical plant protection products. It does, however, authorize the use of substances of natural origin, such as certain insecticides (e.g., pyrethroids from chrysanthemums or azadirachtin from neem trees) ((EC) 2021/1165). Chemical substances that are ubiquitous in the environment are also likely to be found in organic food [13–17,19,20]. The growth of organic farming is remarkable both in Europe and worldwide, probably driven by the growing consumer demand for food that meets environmental and sustainable development challenges.

The description of POFE showed that the chemical content of organic foods has not been widely studied, especially in the EU region. We have collected data for 166 matrices, 209 substances, and 823 matrix–substance pairs, already constituting an interesting database that could be continuously updated as research in this field progresses. Data distribution (characterized by SI) shows that the majority of matrices, chemicals, and pairs have fewer

than 10 values in POFE. A considerable number of variables [74 (44.6%) matrices, 110 (52.6%) chemical substances, and 738 (89.7%) matrix–substance pairs] were investigated in a single study (values in parenthesis in Figures 3, 5 and 7), highlighting the lack of data and the need for studies in this area. It also showed that many substances that may have harmful effects on human health have not been studied in the organic food literature, for example, newly formed compounds during processing (acrylamide, PAHs) or substances migrating from materials in contact with foodstuffs (bisphenols, phthalates, per- and polyfluoroalkylated) remain largely unexplored.

As for the strengths of this work, it should be emphasized that our approach to data search and selection, as well as the structure of the database, allows for the addition of further data, studies, or articles as they become available in order to keep the table up to date. It will also be possible to include data on other types of chemical contaminants that have not yet been studied or even contaminants of biological origin such as mycotoxins, which are substances of concern in organic production and whose presence in food products can pose a threat to global food security [42].

4. Conclusions

The main objective of this work was to build an updatable database based on an extensive literature search for collecting levels of chemical substances present in organic food in the EU region. At this stage, the study does not aim to compare the data collected with other agricultural production methods or even to assess the potential impact on health.

The constructed database, POFE, represents a pioneering effort, being the first to compile already published data on chemicals present in organic foods within the EU market. Our comprehensive description of the database and the heterogeneity observed in the results have enabled us to highlight significant gaps in the current literature concerning the chemical analysis of organic foods. Despite this shortcoming, our results provide a valuable tool for determining the effort required to achieve the POFE. This is particularly important given the increasing consumption of organic food in the EU and the corresponding need to understand the exposure risks associated with organic production methods. With this in mind, ongoing efforts to expand and refine the database will provide a more solid understanding of the chemical content of organic food. This is crucial to understanding how this production method affects exposure levels, as current knowledge does not yet allow definitive conclusions to be drawn about concentration levels in organic food compared with other farming practices. This future research will enable more accurate and comprehensive assessments to be made of the potential benefits and risks associated with consuming organic food.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/data9070089/s1, Table S1: Criteria for selection based on language, title, abstract and data availability; Table S2: Elements of the FoodEx 2 level 2 groups; Table S3: Elements of the database table columns; Table S4: Elements of the substance groups; Figure S1: Matrix table of substance groups (rows) versus FoodEx groups (columns). Numbers cells at intersection represent the number of studies for the pair substance group—FoodEx group.

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