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Influence of Selected Factors on the Quality of Seasonable Vegetables Using Asparagus As An Example

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Abstract Asparagus is a green vegetable, available only seasonally, and interest in it in Europe is growing because of its health benefits. However, since there is a lack of studies in this area, the aim of the article was to identify risk factors affecting the quality and consumption of asparagus as an exemplary seasonal vegetable. The current state of knowledge on the nutritional, dietary and medicinal properties of edible asparagus was presented, an analysis of notifications reported on asparagus in the Rapid Alert System for Food and Feed (RASFF) was carried out, and a bibliometric analysis of scientific articles on asparagus was performed using VOSviewer. Its was found that the most commonly reported hazards in asparagus were pesticide residues, heavy metals and adulteration. Although the vast majority of asparagus available in the European Union (EU) comes from Europe, the majority of RASFF notifications concern products from Peru, as well as Asian countries. Therefore, the attention of the food safety supervisory authorities of EU countries should focus on controls at the EU external border and concern imported products.

Keywords: *asparagus, quality, metals, pesticides, production, import, European Union*

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1. Introduction

The latest nutritional research indicates that consuming adequate amounts of fruits and vegetables daily has an impact on the development of non-communicable diseases. A meta-analysis showed that consuming more fruits and vegetables results in lower mortality and reduces the risk of diseases such as cancer, cardiovascular disease (CVD), type 2 diabetes, and inflammatory bowel disease [1,2]. Wang et al. (2021) pointed out that not only the quantity but also the ratio between vegetables and fruits plays an important role in fruit and vegetable consumption. They showed that the reduction in mortality risk is significantly lower with the consumption of two servings of fruit and three servings of vegetables per day [3].

The need to increase fruit and vegetable consumption was previously highlighted by the 2019 EAT-Lancet Commission Report. This report demonstrated that food and nutrition have undergone globalization and industrialization over the past few decades. The significant impact of food production on the natural environment has been recognized, leading to growing environmental pollution, food waste, and the unused food waste. In recent years, the importance of food choices and their impact on the natural environment has received increasing attention. The number of scientific studies examining the relationship between diet, human health, and the natural environment has significantly increased.

The modern diet should consist primarily of vegetables and fruits, whole grains, legumes, nuts, and unsaturated oils, while limiting meat consumption, especially red meat, and minimizing saturated fats and refined sugars. The report also highlights the increase in diseases related to poor nutrition and the rising incidence of obesity, especially among adolescents. The EAT–Lancet Commission has proposed a diet for the planet (Food Planet Health), which takes the planet's interests more into account, including better use of the planet's resources. This should be a diet rich in plant-based foods and reduced in animal products, ensuring both a healthier life and environmental benefits. The Commission points out that diets close to Food Planet Health include the flexitarian diet, the DASH (Dietary Approaches to Stop Hypertension) diet, the MIND (Mediterranean – DASH Intervention for Neurodegenerative Dysfunction) diet, and the Mediterranean diet [4]. All of these diets are based on a higher consumption of vegetables and fruits. The authors of the report emphasize the importance of seasonal vegetables and locally grown crops in this diet.

Food consumption patterns and eating habits vary throughout the year. When planning menus, we also use weekly or decade-long planning, striving to ensure variety and diversity in our diet. This planning highlights the seasonality of products and dishes. Factors influencing seasonality in nutrition include climate, lifestyle, dietary and cultural patterns, and religion. Environmental factors, especially climatic factors, are more pronounced in countries with significant differences between seasons in terms of temperature and humidity. Eating more seasonal foods is one suggestion for shifting to more sustainable consumption patterns, based on the assumption that this can reduce the environmental impact of our diet. To a greater or lesser extent, we are influenced by seasonality, particularly in the supply of fruits and vegetables [5].

Seasonal foods can be defined as globally seasonal and locally seasonal. The United Kingdom's Department for Environment, Food and Rural Affairs (DEFRA) has proposed a global definition of seasonal food, which defines it as being produced during the natural production season but consumed anywhere in the world. Local seasonal food, on the other hand, is produced during the natural production season and consumed in the same climate zone [6]. Promoting seasonal food, especially local food, is consistent with a sustainable diet that reduces negative environmental impact [7].

Research conducted by Wallnoefer et al. (2021) showed that consumers perceive local food as safer, healthier, and of higher quality. Consumers are undeterred by the higher price of local, seasonal food, assuming that it contributes to the development of the local economy and community. They attach less importance to the environmental impact of local and seasonal food, with consumer ethnocentrism taking precedence [8]. Asparagus is an example of a seasonal vegetable with both global and local significance. Besides its undeniable sensory benefits, asparagus also boasts health benefits and is also economically significant for local communities.

Asparagus (*Asparagus officinalis* L.) is one of the seasonal vegetables. In 2014–2023 asparagus accounted for only 0.5% of EU vegetable production [9]. Meanwhile, asparagus consumption was, for example, 1.4 kg/capita/year in Germany in 2023/2024 [10] and 0.6 in Spain in 2021 [11]. In comparison, the consumption of various other vegetables across the European Union in 2022 was: 60.6 kg/capita/year (for potatoes), 34.3 (tomatoes), 9.7 (onions), 0.9 (peas) and 0.7 (beans) [12]. However, it is worth noting that these are vegetables available all year round, while there is a lack of studies on seasonal vegetables, which are becoming increasingly popular because of their health properties.

Therefore, the aim of this article was to present the current state of knowledge on the nutritional, dietary and medicinal properties of edible asparagus, to identify risk factors affecting the quality and consumption of asparagus based on notifications reported in the Rapid Alert System for Food and Feed (RASFF), and to conduct a bibliometric analysis showing the relationship between the word "asparagus" and other keywords. The achievement of this objective made it possible for the first time to present asparagus as an example of a seasonal vegetable in such an interdisciplinary and holistic way. This study is mainly review-based, but it also includes a research aspect in the form of the aforementioned analyses.

2. Materials and Methods

A literature review was conducted on the composition and properties of asparagus. Data on asparagus cultivation, production were taken from the Faostat database [13], while data on imports and exports were taken from the Eurostat database [14].

In turn, data on hazards related to asparagus was extracted from the archived and officially available RASFF databases and concerned period 2014–2023. All notifications concerning asparagus during the indicated period were taken into account, and to filter the data, the word 'asparagus' was used in the "Subject" column of table with the exported data. [15,16].

The data was then combined in one source table consisting of the following dataset: year, product category, product, hazard, notification type, notifying country, country of origin and hazard category. The data was subsequently processed in Microsoft Excel 365 (Microsoft Corporation, Redmond, DC, USA) using the following functions: sorting, filtering and pivot tables.

A search for scientific papers with word "asparagus" in the Web of Science database was also carried out, yielding 5,338 results (i.e. scientific works) [17]. These were then exported to text files and were subjected to bibliometric analysis in VOSviewer 1.6.20 using the following settings: analysis type – co-occurrence, analysis unit – authors' keywords and minimum number of keyword occurrences – 15. This condition was met by 76 keywords, and optimisation in terms of the minimum number of keyword occurrences was carried out in order to make the maps obtained (i.e. network visualisation and overlay visualisation) more readable. It should also be noted that each of these keywords was associated with at least one other word, so there was no need to exclude individual (unrelated) words from the visualisations.

This was also followed by a separate search with an indication of the hazards most commonly found in asparagus, using the phrase: "asparagus AND pesticide* OR asparagus AND metal* OR asparagus AND adulteration". Therefore, the logical operators 'AND' and "OR" were used, as well as the sign "*", which made it possible to find keywords with different grammatical forms in the scientific works. This search yielded 181 results (that is, the scientific works). When setting the minimum number of occurrences to 1 during map creation, the maps consisted of 165 keywords. However, most of them were not associated with any other words (they constituted single-element clusters). Therefore, they were eliminated from the visualisations, and finally, these maps consisted of only 44 keywords.

3. Results

Asparagus is a dioecious plant, meaning male and female plants are grown separately. Farmers prefer male plants because they are more productive and of better quality. One of the criteria for culinary classification of asparagus is their colour. Asparagus comes in white, green, olive, and purple. There are even pink varieties. Asparagus plantations are typically maintained for no longer than 10–12 years, because in this period they produce the highest quality and quantity of harvest. Asparagus is grown in various climates, but the best growing season occurs in temperate climates with temperatures not exceeding 30°C. Properly prepared soil is a crucial factor in the quantity and quality of asparagus. Asparagus is primarily harvested by hand, as machine harvesting often damages the delicate shoots. Labour shortages during the asparagus production season are the biggest problem facing farmers on large farms [18,19].

3.1. Composition and Properties of Asparagus

Asparagus is valued primarily for its unique flavour and aroma. Young, tender shoots contain over 90% water. The content of basic nutrients is presented in Table 1.

Table 1. Basic composition of the edible part of the asparagus shoot

Ingredient	Content (g/100g DW)
Protein	46.2–48.8
Fat	3.4–4.7
Total carbohydrates	17.3–21.4
Glucose	0.6–5.7
Total dietary fibre	21.0–24.0
Soluble dietary fibre	22.8–23.8
Ash	8.9–9.3

Source: own elaboration based on [20,21]

Asparagus contains various bioactive substances, such as protein and non-protein nitrogen, saponins, crude and soluble fibre, minerals, phenolic compounds, flavonoids, and organic acids (Table 2).

Table 2. Content of bioactive compounds in asparagus

Ingredient	Content	Reference
Free amino acids	1740 ± 243 mg 100 g-1 DW	[22]
Saponins	0.14 – 0.80 g kg-1 fresh weight (FW)	[23]
Total dietary fibre	58.10 ± 0.35 g/100g DW 22.85 ± 1.00 g/100g DW	[20] [21]
Insoluble dietary fibre	45.72 ± 0.28 g/100g DW	[20]
Soluble dietary fibre	12.38 ± 0.56 g/100g DW	[20]
Organic acids	2.7 ± 0.3 – 3.5 ± 0.4 g kg-1FW	[24]
Total phenolic	124.09±2.01 – 425.82±5.07 mg/kg	[25]
Total flavonoid	70.53±0.95 – 279.66±4.16 mg/kg	[25]
Ash	8.90 ± 0.17 g/100 g DW 9.34 ± 0.01 g/100 g DW	[20] [21]

Source: own elaboration

The data in Table 2 indicate slight variations in the results of studies conducted by different authors. Analysis of these results suggests two reasons for these differences. First, the authors conducted their studies on different asparagus varieties. Another factor was likely the research methodology. The authors used different methods, which could have caused the differences in results. However, regardless of this, the results were often consistent or subject to slight fluctuations.

The edible part of asparagus is also a source of minerals. Potassium, sodium, calcium, magnesium, and iron were detected in asparagus samples. These elements were found to form an ascending series: K > Ca > Mg > Na > Fe. Zinc, however, was present in trace amounts, and copper and manganese were absent [20]. However, Kiliçgün (2020) found zinc content of 0.62 mg/100g, copper of 0.20 mg/100g, and manganese of 0.6 mg/100g in asparagus infusions [26]. Guan et al. (2015) reported that asparagus contained significant amounts of selenium, up to 0.56 mg/kg, which is comparable to the Se content in mushrooms [27]. The presence of Se in asparagus is also confirmed by the research of Gao et al. (2024). They found Se content in 30 *Asparagus officinalis* L. varieties ranging from 1.12 to 2.9 µg/100g dry weight (DW) [28].

Among the vitamins identified in asparagus, provitamins in the form of carotenoids, vitamin C, and B vitamins have been identified. Asparagus is a good source of vitamin C, although its content can vary significantly. Kiliçgün (2020) reports that the vitamin C content in asparagus is 43.31±0.20 mg/100g [26]. Chen et al. (2017), in turn, examined the vitamin C content in green asparagus and found that it varied greatly depending on the variety, ranging from 24.2 to 59.1 mg/kg. Cultivation method also influences vitamin C content [25]. Ku et al. (2018) demonstrated the effect of conventional and organic cultivation on the content of bioactive compounds. Vitamin C in conventionally cultivated asparagus ranged from 9.28 ± 0.88 to 9.41 ± 0.93, while in organically cultivated asparagus it was 9.86 ± 0.78 mgAsc/g DW [29]. Chileh Chelh et al. (2023) noted that wild asparagus contains less vitamin C than cultivated asparagus [30].

Cultivated asparagus contained an average of 22.7 mg/100g fresh weight (FW), while wild asparagus ranged from ~16–17 mg/100g FW. There are many more factors shaping the quality of asparagus that influence the content of bioactive substances in asparagus. Mastropasqua et al. (2026) draw attention to the asparagus harvest period and the cultivation method: horticultural or field. In their study, they applied different light colours and wavelengths to the quality parameters of asparagus grown in horticulture. Light exposure had different effects on various quality parameters. However, irradiation affected the content of vitamin C, carotenoids, chlorophyll, and anthocyanins [31].

Asparagus has a rich composition of bioactive compounds that act on the bodies of humans and animals. The plant has been used in folk medicine since ancient times. It was used medicinally in China, India, Egypt, Rome, and Greece. In these countries, asparagus was primarily known as an aphrodisiac [32,33]. In modern times, this has been confirmed by animal experiments. The species *Asparagus racemosus* L. possesses particular aphrodisiac properties [34].

The therapeutic effects of asparagus have also been observed in other diseases, but not all of these uses have been clinically confirmed (Figure 1).

Asparagus extracts possess strong antioxidant properties, and the colour of the vegetable is important here, as purple asparagus contains more anthocyanins and thus scavenges more 2,2-diphenyl-1-picrylhydrazyl (DPPH) radicals [35]. This vegetable is characterized by a high content of xylose, inulin, flavonoids, and saponins, which favourably influences the growth of probiotic bacteria of the *Lactobacillus* and *Bifidobacterium* strains [20]. Since ancient times, asparagus has been used as a diuretic. However, this effect has only recently been demonstrated in animal studies [36]. However, the characteristic odour of urine after eating asparagus remains a subject of ongoing research and is still unresolved. Recent studies indicate that not all asparagus consumers experience this odour, and it may be a genetically determined trait [37].

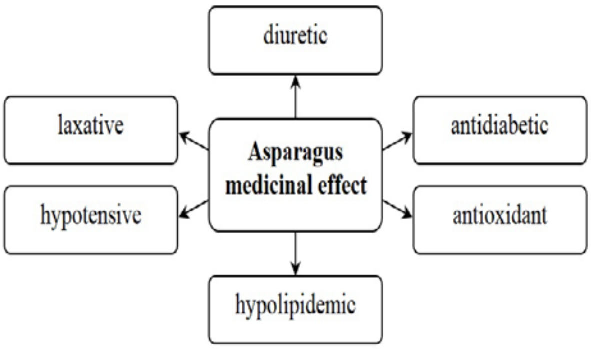

Figure 1. Asparagus medicinal effects. Source: own elaboration

Zhao et al. (2011) conducted research on the hypoglycemic effects of asparagus in rats [38]. Zhu et al. (2010) demonstrated the hypolipidemic properties of asparagus in mice [39]. Asparagus, due to its fibre content, has also been shown to have anti-obesity properties. The species *Asparagus cochinchinensis* (Lour.) Merr. has been shown to have a particularly positive effect in this regard [40].

Asparagus, due to its various forms of fibre, has a laxative effect, confirmed in animal experiments [41]. Moreover, asparagus of different varieties are increasingly used in functional foods and dietary supplements [42,43,44,45].

3.2. Cultivation, Production and Trade of Asparagus in the European Union

Asparagus is a plant widespread worldwide, with approximately 300 species identified to date. Asparagus was known to the Greeks and Romans in ancient times [37]. It has spread from Asia Minor and the Mediterranean basin and is now cultivated in North and South America, Greece, France, the Netherlands, Germany, Spain, Hungary, and England. Currently, asparagus is grown on a total area of approximately 1.6 millions of hectares worldwide (Figure 2).

In Asia, asparagus is mainly farmed in China (between 2014 and 2023 it accounted for an average of 99% of the continent's cultivated area), in the Americas in Peru (41%) and Mexico (38%), while in Europe it is grown in Germany (36%), Spain (22%) and Italy (12%) [13]. In turn, world asparagus production quantity (in million tonnes) in the period 2014–2023 was presented in Figure 3.

Asparagus production was more than 8.5 million tonnes each year, with about 88% (on average over the whole presented period) of this vegetable produced in Asia (mainly in China), 8% in Americas (primarily in Peru and Mexico) and only 4% in Europe (mostly in Germany), so these are similar countries as for the cultivation of this vegetable. Interestingly, although when it comes to the asparagus yield, other countries may be leading the way. Thus, in Asia, the highest average yields between 2014 and 2023 were in Iran, Thail and and Israel, respectively: 25, 14, 12, while in China it was only 5 tonnes/ha. In the Americas, Peru and Mexico were similarly dominant countries (12 and 9 tonnes/ha respectively). In Europe, however, the highest yields were in Poland (10 tonnes/ha), while in Germany it was only 5 tonnes/ha [13].

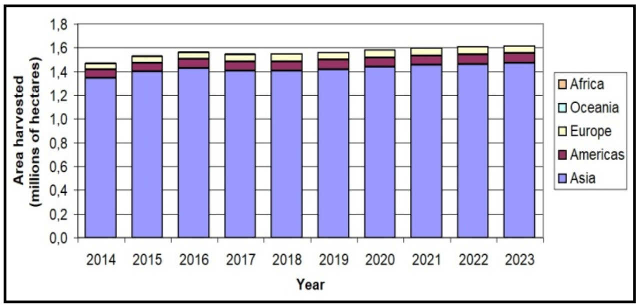

Figure 2. World asparagus cultivation (in million of hectares) in 2014–2023. Source: own elaboration based on [13]

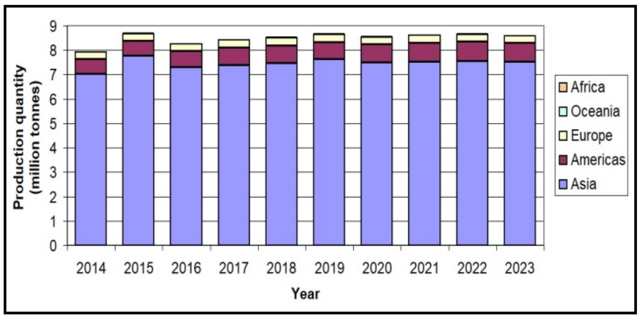

Figure 3. World asparagus production (in million tonnes) in 2014–2023. Source: own elaboration based on [13]

Comparison of production and import of asparagus into the European Union (in thousands of tonnes) in 2014–2023 were shown in Figure 4.

The average European asparagus production between 2014 and 2023 was around 311 thousands of tonnes, while imports averaged 34 thousands of tonnes. In Europe, asparagus is mainly produced in Germany (39% of European production on average), as well as in Spain (18%) and Italy (15%). It should therefore be noted that EU imports account for only 11% on average of European production [13]. Most of the imported asparagus came from Peru (78% on average in the mentioned period), and also from Mexico (18%) [14].

It is worth noting the comparison between the import and export of asparagus outside the EU (Extra_EU) and the import and export within the EU (Intra_EU) in thousands of tonnes in 2014–2023 (Figure 5).

Average exports outside the EU (10 thousands of tonnes) accounted for approximately one-third of the already mentioned imports from outside the EU (34 thousands of tonnes) in 2014–2023. A more detailed analysis shows that the main importers of asparagus from outside the EU were Spain, the Netherlands and the United Kingdom (until Brexit), while the main exporters outside the EU were France, the Netherlands and Italy. In turn, as regards intra-EU trade, average imports and exports during the period indicated amounted to approximately 64 and 62 thousands of tonnes respectively, and the small difference between these two types of flows may suggest re-exports. Within the EU, asparagus was mainly imported by Germany, France and Belgium, whereas it was exported by Spain, the Netherlands and Italy (the same countries that mainly exported asparagus outside the EU). In this context, it is also worth noting that the Netherlands is an important country for European asparagus trade both outside and within the EU.

3.3. Notifications Concerning Asparagus Reported in the RASFF

Between 2014 and 2023, there were 41 notifications concerning asparagus in the RASFF (Table 3).

In this period, the majority of them referred to the presence of pesticide residues (e.g. chlorpyrifos, methomyl) or heavy metals (cadmium and lead). Most were information notifications, but alerts and border rejections were also reported. In turn, the notifying countries were most often the Netherlands, Germany France and Spain, and the reported products predominantly originated from non-European Union countries (more than 80% of notifications), such as: Peru, Dominican Republic, China, and India. It is worth remembering that most of the asparagus imported into the European Union market came from Peru.

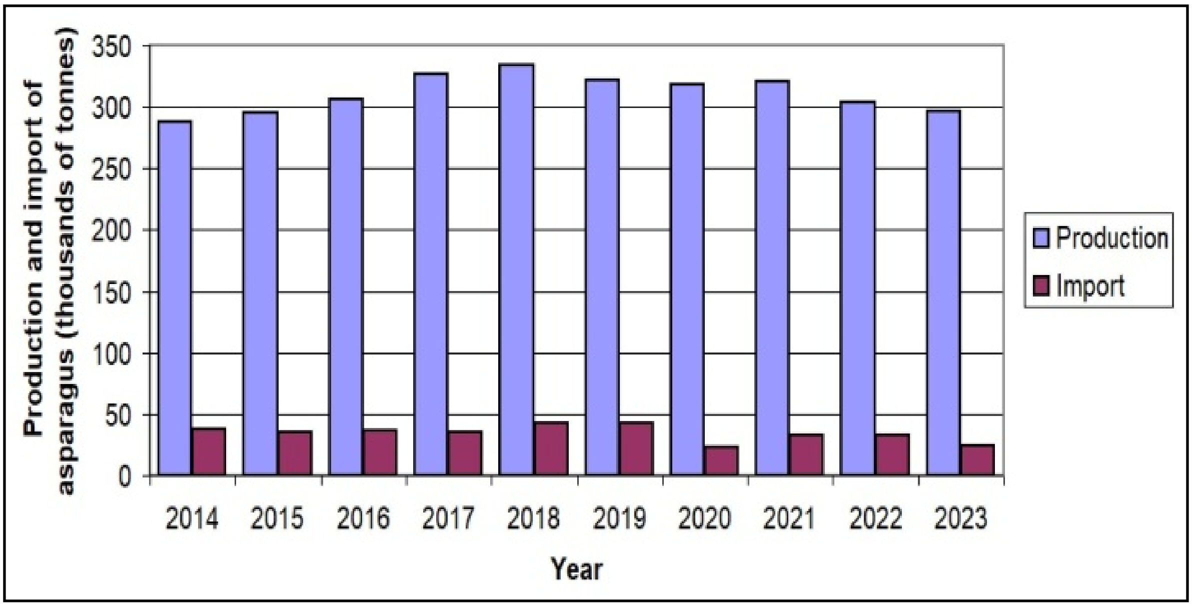

Figure 4. Comparison of production and import of asparagus into the European Union (in thousands of tonnes) in 2014–2023. Source: own elaboration based on [13,14]

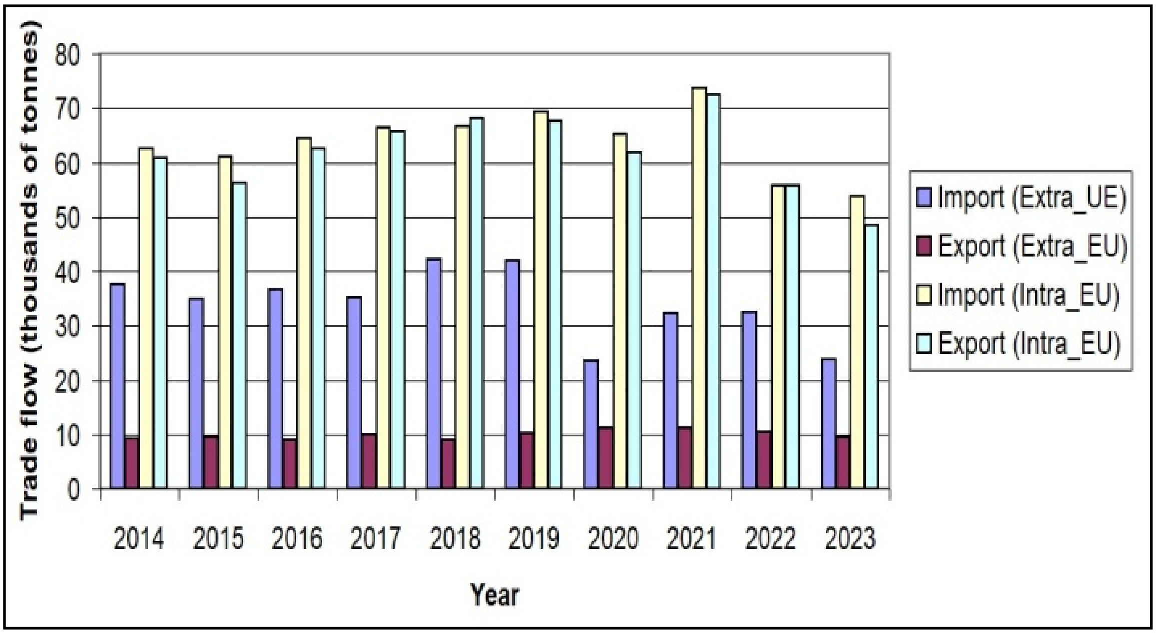

Figure 5. The comparison between the import and export of asparagus outside the EU and the import and export within the EU (in thousands of tonnes) in 2014–2023. Source: own elaboration based on [14]

Table 3. Notifications concerning asparagus notified in the RASFF in 2014–2023

Year	Product category	Product	Hazard	Notification type	Notifying country	Country of origin
2014	Fruits and vegetables	Asparagus	Glass fragments	Information	Germany	China
2014	Fruits and vegetables	Green asparagus	Benzalkonium chloride (BAC)	Information	Netherlands	Peru
2014	Fruits and vegetables	Asparagus beans	Chlorpyrifos	Border rejection	Italy	Dominican Republic
2014	Fruits and vegetables	Chilled asparagus peas	Chlorpyrifos	Border rejection	France	Dominican Republic
2015	Fruits and vegetables	Asparagus	Too high content of sulphite	Alert	Austria	China
2015	Fruits and vegetables	Asparagus	Sulphite	Alert	Austria	China
2015	Soups, broths, sauces and condiments	Asparagus soup	Altered organoleptic characteristics	Information	Denmark	Netherlands
2015	Fruits and vegetables	Green asparagus	Methomyl	Alert	Netherlands	Peru
2015	Fruits and vegetables	Asparagus peas	Chlorpyrifos-methyl	Border rejection	France	Dominican Republic
2016	Fruits and vegetables	Asparagus	Cadmium	Information	Belgium	Peru
2016	Fruits and vegetables	Green asparagus	Chlorpyrifos	Information	Netherlands	Peru
2017	Fruits and vegetables	Quick-frozen green asparagus	Cadmium	Information	Spain	Peru
2017	Fruits and vegetables	Green asparagus	Poor state of preservation	Border rejection	Spain	Mexico
2018	Soups, broths, sauces and condiments	Green asparagus soup	Improper production	Information	France	France
2018	Fruits and vegetables	Asparagus	Methomyl	Information	Netherlands	United States
2018	Fruits and vegetables	Canned green asparagus	Cadmium	Border rejection	Spain	Peru
2018	Fruits and vegetables	Asparagus tips	Methomyl	Alert	Netherlands	Peru
2018	Fruits and vegetables	Green asparagus	Cadmium	Border rejection	Spain	Peru
2018	Fruits and vegetables	Asparagus	Cadmium	Information	Spain	Peru
2018	Fruits and vegetables	Green asparagus	Cadmium	Information	France	Peru
2018	Fruits and vegetables	Organic asparagus salad	Sesame	Alert	Netherlands	Belgium
2020	Dietetic foods, food supplements and fortified foods	Asparagus roots	Lead	Alert	Netherlands	Morocco
2020	Fruits and vegetables	Green asparagus	Methomyl	Information	Netherlands	Peru
2021	Fruits and vegetables	Asparagus beans	Carbofuran	Information	Germany	Sri Lanka
2021	Dietetic foods, food supplements and fortified foods	Food supplement	Asparagus sarmentosus	Border rejection	Spain	United Kingdom
2021	Fruits and vegetables	Asparagus beans	Chlorpyrifos, profenofos	Border rejection	Germany	India
2021	Other food product / mixed	Green asparagus	Chlorpyrifos, clothianidin, fenobucarb, isocarbophos, isoprocarb, omethoate, pyridaben, thiamethoxam	Alert	Germany	China
2021	Fruits and vegetables	Asparagus beans	Acephate, hexaconazole, methamidophos	Information	Germany	India
2022	Fruits and vegetables	Green asparagus	Chlorpyrifos	Alert	Belgium	Peru
2022	Dietetic foods, food supplements and fortified foods	Food supplement	Asparagus racemosus	Border rejection	Poland	India
2022	Dietetic foods, food supplements and fortified foods	Food supplement	Asparagus racemosus	Border rejection	Poland	India
2022	Fruits and vegetables	Green asparagus	Cadmium	Information	Netherlands	Peru
2022	Fruits and vegetables	Asparagus mini	Chlorpyrifos	Alert	Netherlands	Peru
2023	Soups, broths, sauces and condiments	Asparagus soup	Gluten, selery	Alert	Netherlands	Netherlands
2023	Fruits and vegetables	Asparagus beans	Acephate, bifenthrin, methamidophos, methomyl, propiconazole	Information	Germany	Mexico
2023	Fruits and vegetables	Green asparagus	Lead	Information	Finland	Spain
2023	Fruits and vegetables	Asparagus	Imidacloprid, isoprocarb, prometryn	Information	Spain	China
2023	Fruits and vegetables	Asparagus	Copper, lead	Information	Switzerland	Spain
2023	Fruits and vegetables	Asparagus beans	Chlorfenapyr, isocarbophos	Information	Germany	China
2023	Fruits and vegetables	Asparagus beans	Carbofuran, chlorothalonil, profenofos	Information	Germany	Sri Lanka
2023	Fruits and vegetables	Asparagus beans	Fenobucarb	Border rejection	Germany	Sri Lanka

Source: own elaboration based on [15,16].

4. Discussion

4.1. Potential Hazards Associated with the Consumption of Asparagus

4.1.1. Pesticide Residues

Fungicides, herbicides, and insecticides are three groups of compounds collectively known as pesticides. They are used in agricultural crops to increase yields and protect against diseases and pests [46,47]. However, excessive or inappropriate use of pesticides causes their accumulation in crops and their derived products, posing a threat to humans and the environment. Pesticides can cause acute, subacute, and long-term toxicity, causing cancer, neurological diseases, hormonal disruption, allergic reactions, and affecting fertility [48,49]. As mentioned earlier, the most frequently reported pesticides in asparagus in the RASFF were chlorpyrifos and methomyl.

Chlorpyrifos is an organophosphate pesticide widely used in fruit and vegetable crops. It was banned in the European Union in 2020 [50]. It was also banned in some countries, such as the United States, but its use has been reinstated in many states. Chlorpyrifos is primarily an insecticide used to control insects in agriculture and indoors, such as cockroaches. Its harmfulness to humans stems from blocking the enzyme acetylcholinesterase (AChE), which is involved in nerve transmission. Therefore, the consequence of contact with this pesticide is neurological disorders, particularly dangerous for children [51].

Methomyl is also an insecticide with a very broad spectrum of action, not only against insects but also against nematodes, arthropods, and fish. It is a very toxic compound, classified as Class II. Unfortunately, research shows that insects are developing resistance to this chemical. Methomyl inhibits AChE activity and leads to nerve damage [52,53]. The EU has a pesticide limit of 0.01 mg/kg for all fruits and vegetables [54].

Imidacloprid is an insecticide used in agriculture for decades. It was considered a relatively safe agent with a broad spectrum of action against insects. However, recent studies have indicated its far-reaching toxic effects on organisms other than insects. It has been found to be harmful to bees, aquatic organisms, and bats. Scientists have identified microorganisms that can accelerate the degradation of imidocloprid in the environment [55].

Isoprocarb, another carbamate compound, is widely used in agriculture and aquaculture, after methomyl. It is neurotoxic to organisms by blocking AChE and inducing oxidative stress, as confirmed by studies on the model organism *Danio rerio* [56]. Studies have shown that isoprocarb is also toxic to the environment, including neurotoxic effects on composting earthworms (*Eisenia fetida*) [57].

Prometryn, a triazine herbicide found in asparagus, is commonly used in agriculture to inhibit the growth of leafy and herbaceous plants. Unfortunately, in recent years, significant accumulation of this compound has been detected in soil, water, and animal organisms. Studies on the model organism *Danio rerio* have shown that prometryn has a neurotoxic effect on zebrafish embryos and leads to oxidative stress and cell death. It has also been found to disrupt the development of *Danio rerio* embryos [58]. Prometryn is characterized by hepatotoxicity, as confirmed in studies on the edible fish tilapia (*Oreochromis niloticus*) [59].

4.1.2. Heavy Metals

Many scientific studies indicate the toxic effects of heavy metals on humans and animals [60,61,62] [63,64,65,66]. Heavy metals in the environment most often come from two sources. The first is natural processes such as earthquakes, volcanic eruptions, and rock weathering and the second is human activity.

Anthropological sources of environmental pollution with heavy metals include industry, agriculture, municipal and industrial sewage, and landfills. Sources of heavy metals in agriculture include fertilizers, sewage poured onto crop fields, waste of unknown origin stored in fields, and pesticides [67]. Heavy metals such as cadmium and mercury were most commonly notified in asparagus in the RASFF.

Industrial sources of metal pollution include mining, smelting, the metallurgical industry, glassworks, and others. Sutkowska et al. (2020) conducted a study of soil contamination in the Upper Silesia region in southern Poland, where industry is concentrated, and found that heavy metal contamination varied across different soil layers. In the surface layer, metal concentrations were arranged in the series Pb > Cd > Zn. In the deeper layer, the concentration varied from Zn > Cd > Pb. The researchers found that the amount of heavy metals in the soil exceeded the geochemical background by 2.5 to 18.1 times [68].

Permissible metal residues are specified in the EU Regulation 2023/915. For root and tuber vegetables, residues of 0.1 mg/kg of fresh weight are permitted [69]. As demonstrated by Biddau and Cidu (2017), the content of metals and metalloids in asparagus is significantly influenced by their content in the soil [70]. Furthermore, other studies have shown that the metal content in vegetables, including asparagus, is influenced by climatic and soil factors, cultivation method, and asparagus variety [71,72,73].

A review of studies by various authors shows that asparagus is a vegetable that particularly accumulates metals and metalloids. Biddau and Cidu (2017) demonstrated that asparagus grown in mining areas contained significantly more Cd. Therefore, before deciding to cultivate asparagus, the soil environment and geochemical background should be assessed [70].

4.1.3. Other Hazards

The rich composition of bioactive compounds in asparagus, particularly species such as *Asparagus racemosus* (Willd.), *Asparagus cochinchinensis* (Lour.) Merr., and *Asparagus officinalis* L., leads to their use in dietary supplements and functional foods [74,75,76]. Lack of authenticity and various forms of adulteration are the most frequently identified irregularities in dietary supplements and nutriceuticals containing asparagus. The most common adulteration involves substituting the declared asparagus species with another plant. Other adulterations include the lack of a geographical origin of this vegetable and incorrect labelling of supplements.

In the RASFF reported several notifications of irregularities in the "Dietetic foods, dietary supplements, and fortified foods" category. To prevent such irregularities, various methods for identifying adulterations are applied, using state-of-the-art physicochemical analysis methods [77,78,79,80].

4.2. Bibliometric Analysis of Works with the Word "asparagus"

Figure 6 shows the network visualization and Figure 7 the overlay visualisation, generated in VOSviewer 1.6.20. Both charts consist of 76 keywords and show direct or indirect links between the word "asparagus" and other keywords indicated by authors of scientific papers. Figure 6 illustrates six clusters (marked in different colours), with a cluster grouping together issues more frequently mentioned by authors of scientific works next to each other in keywords than those found in other clusters. In turn, Figure 7 shows the years in which the researchers addressed particular aspects, with issues raised in the most recent studies (from 2020 onwards) marked in yellow.

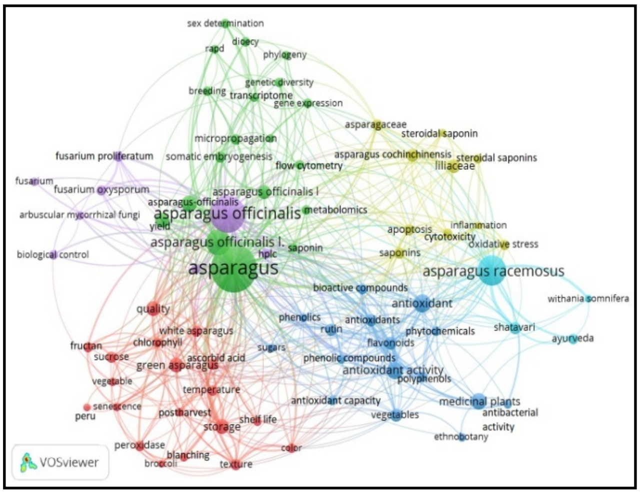

Figure 6. Network visualisation of the links between the keyword "asparagus" and other words generated in VOSviewer 1.6.20. Source: own elaboration based on data from [17]

Asparagus officinalis is located in the centre of Figure 6. This indicates that most publications concern this species of asparagus. Other species, such as *Asparagus cochinchinensis*, are located far from the centre. The green cluster groups topics related to genetics, research and cultivation. The light blue cluster presents words related to the species *Asparagus racemosus*. The purple cluster, on the other hand, groups issues related to the hazard of *Fusarium* fungi observed in asparagus crops, and is the only cluster that indicates hazards that may occur in this vegetable. The red cluster presents words related to bioactive compounds and nutrients found in asparagus, such as sucrose, fructans, ascorbic acid, chlorophyll and peroxidase. There are also keywords related to the storage conditions and sensory characteristics of asparagus. It is also important to note in this cluster Peru as the country of origin and the largest exporter of this vegetable to the European Union. The dark blue cluster groups together issues related to compounds found in asparagus, such as phenols, polyphenols, sugars, flavonoids and rutin, as well as words related to an antioxidant properties. The olive-coloured cluster, on the other hand, includes words such as apoptosis, cytotoxicity and oxidative stress.

As for the latest scientific research on asparagus, it referred to the transcriptome (so it concerns genetics), metabolomics (so it covers chemical processes involving metabolites), and polyphenols activity (the yellow colour in Figure 7).

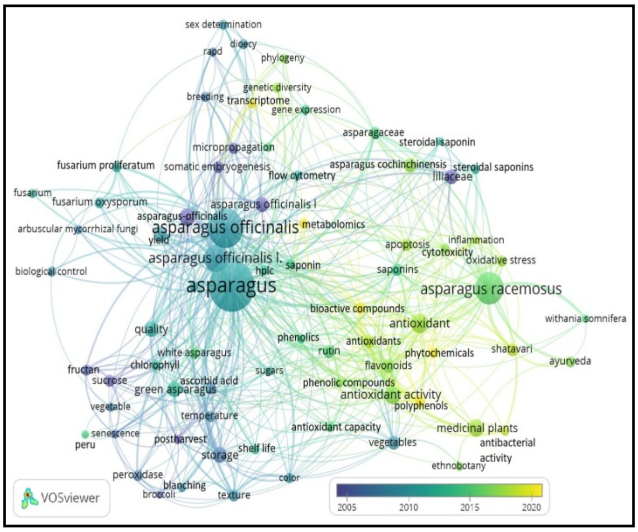

Figure 7. Overlay visualisation of the links between the keyword "asparagus" and other words generated in VOSviewer 1.6.20. Source: own elaboration based on data from [17]

In turn, Figure 8 and Figure 9 show the links of keywords related to the hazards most frequently identified in asparagus. The phrase "asparagus AND pesticide* OR asparagus AND metal* OR asparagus AND adulteration" was used to search for scientific works on this topic. After optimisation (details provided in section 2. Materials and Methods), 44 keywords were included in the visualisations presented.

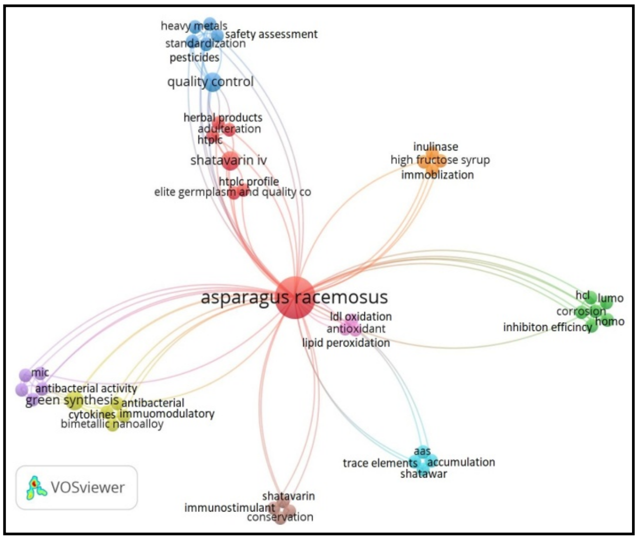

Figure 8. Network visualisation of the links between the keyword "asparagus AND pesticide* OR asparagus AND metal* OR asparagus AND adulteration" and other words generated in VOSviewer 1.6.20. Source: own elaboration based on data from [17]

It is noteworthy that research in this area has not yet been undertaken on the most common asparagus species, Asparagus officinalis, but only on another species, Asparagus racemosus (red cluster in the centre of Figure 8). This cluster also includes adulteration, while slightly above, in the dark blue cluster, are pesticides and heavy metals. However, very importantly, two issues closely related to the prevention of these hazards can also be identified here, namely quality control and safety assessment. In turn, other clusters contain issues indicating the beneficial properties of asparagus, also indicated in Figure 6, that is, the antioxidant (pink cluster), antibacterial (olive), and immunostimulating (brown) nature.

Finally, it is also worth noting that issues related to the presence of pesticides and heavy metals in asparagus, as well as adulteration, are the subject of recent research, i.e. conducted after 2020 (yellow colour in Figure 9).

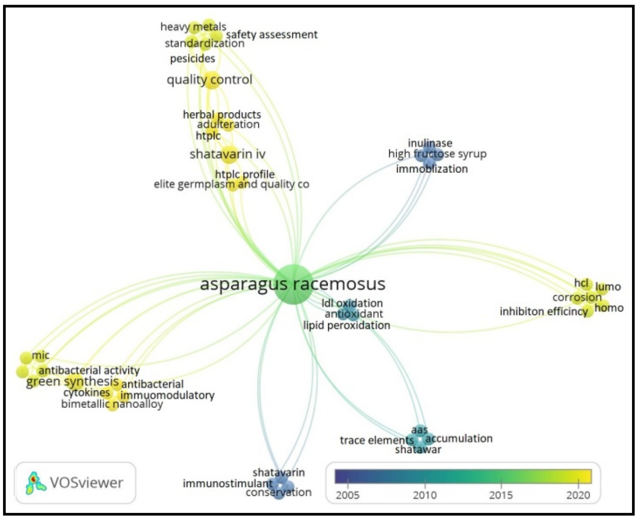

Figure 9. Overlay visualisation of the links between the keyword “asparagus AND pesticide* OR asparagus AND metal* OR asparagus AND adulteration” and other words generated in VOSviewer 1.6.20. Source: own elaboration based on data from [17]

The analysis of possible hazards associated with asparagus consumption is therefore in line with the latest research undertaken by the authors of scientific papers, and it can be assumed that these issues will be further developed. It is also worth noting that in recent years, asparagus has become the subject of particular interest to researchers in many other areas, such as antibacterial activity, immunomodulatory properties and inhibition efficiency.

Conclusions

The increasing interest in asparagus as a green seasonal vegetable in Europe is due to its health benefits. Yet asparagus is mainly grown in Asia (China) and the Americas (Peru and Mexico) and European production accounts for only 4% of total world production. Importantly, however, the vast majority of asparagus available on the EU market is grown in Europe (imports account for just 11% of European production).

Nevertheless, it should be noted that most notifications reported in the European Rapid Alert System for Food and Feed (RASFF) concern products imported from Peru and the Dominican Republic, as well as Asian countries (China, Thailand, India and Sri Lanka). These notifications concern the presence of pesticide residues (e.g. chlorpyrifos, methomyl), heavy metals (cadmium and lead) and adulteration in asparagus. Therefore, the attention of the food safety authorities of particular EU countries should be focused primarily on the control of imported asparagus passing through the EU’s external border.

References

[1] Devirgiliis, C., Guberti, E., Mistura, L., Raffo, A., “Effect of Fruit and Vegetable Consumption on Human Health: An Update of the Literature”, *Foods*, 13(19). 3149. Oct. 2024.

[2] Stanaway, J.D., Afshin, A., Ashbaugh, C., Bisignano, C., Brauer, M., Ferrara, G., Garcia, V., Haile, D., Hay, S.I., He, J., Iannucci, V., Lescinsky, H., Mullany, E.C., Parent, M.C., Serfes, A.L., Sorensen, R.J.D., Aravkin, A.Y., Zheng, P., Murray, C.J.L., “Health effects associated with vegetable consumption: a Burden of Proof study”. *Nature Medicine*, 28. 2066-2074. Oct. 2022.

[3] Wang, D.D.; Li, Y.; Bhupathiraju, S.N.; Rosner, B.A.; Sun, Q.; Giovannucci, E.L.; Rimm, E.B.; Manson, J.E.; Willett, W.C.; Stampfer, M.J.; Hu, F.B., “Fruit and Vegetable Intake and Mortality: Results From 2 Prospective Cohort Studies of US Men and Women and a Meta-Analysis of 26 Cohort Studies”, *Circulation*, 143(17). 1642-1654. Mar. 2021.

[4] Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L.J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J.A., De Vries, W., Majele Sibanda, L., Afshin, A., Chaudhary, A., Herrero, M., Agustina, R., Branca, F., Lartey, A., Fan, S., Crona, B., Fox, E., Bignet, V., Troell, M., Lindahl, T., Singh, S., Cornell, S.E., Srinath Reddy, K., Narain, S., Nishtar, S., Murray, C.J.L., “Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems”, *Lancet*, 393(10170). 447-492. Feb. 2019.

[5] Spence C., “Explaining seasonal patterns of food consumption”, *International Journal of Gastronomy and Food Science*, 24. 100332. Jul. 2021.

[6] Vargas, A.M., de Moura, A.P., Deliza, R., Cunha, L.M., “The Role of Local Seasonal Foods in Enhancing Sustainable Food Consumption: A Systematic Literature Review”, *Foods*, 10. 2206. Sep. 2021.

[7] Pasquariello, R., Bianchi, M., Mari, F., Caso, D., “Fostering local seasonality: An extended value-belief-norm model to understand sustainable food choices”, *Food Quality and Preference*, 120. 105248. Nov. 2024.

[8] Wallnoefer, L.M., Riefler, P., Meixner, O., „What Drives the Choice of Local Seasonal Food? Analysis of the Importance of Different Key Motives”, *Foods*, 10. 2715. Nov. 2021.

[9] Eurostat, “Agriculture, forestry and fisheries / Agriculture / Agricultural production / Crops / Crop production / Crop production in EU standard humidity (from 2000 onwards) / Crop production in EU standard humidity”. [Online]. Available: https://ec.europa.eu/eurostat/databrowser/view/apro_cpsh1__custom_16967318/default/table. [Accessed Jun. 4, 2025].

[10] Statista, “Per capita consumption of vegetables in Germany in 2023/24, by type (in kilograms)”. [Online]. Available: https://www.statista.com/statistics/511711/vegetables-per-capita-consumption-by-type-germany/. [Accessed Jul. 3, 2025].

[11] Statista, “Consumption volume per capita of fresh vegetables in Spain in 2021, by product (in kilograms)”. [Online]. Available: https://www.statista.com/statistics/745474/fresh-vegetables-consumption-per-person-in-spain-2015-by-product/. [Accessed Jul. 3, 2025].

[12] Faostat, “Food balances / Food balances (2010-)”. [Online]. Available: https://www.fao.org/faostat/en/#data/FBS. [Accessed Jul. 3, 2025].

[13] Faostat, “Production / Crops and livestock products”. [Online]. Available: https://www.fao.org/faostat/en/#data/QCL. [Accessed Jul. 10, 2025].

[14] Eurostat, “International trade / International trade in goods (ext_go) / International trade in goods - detailed data (ext_go_detail) / International trade of EU and non-EU countries since 2002 by HS2-4-6 (ds-059341)”. [Online]. Available: https:// ec.europa.eu/ eurostat/web/main/data/database. [Accessed Sep. 23, 2025].

[15] European Commission, "RASFF–Rapid Alert System for Food and Feed". [Online]. Available: https:// data.europa.eu/ data/datasets/restored_rasff? locale=en. [Accessed Mar. 25, 2022].

[16] European Commission, "RASFF Window". [Online]. Available: https://webgate.ec.europa.eu/rasff-window/screen/search. [Accessed Jan. 20, 2025].

[17] Web of Science, "Search". [Online]. Available: https:// www.webofscience.com/ wos/ woscc/basic-search. [Accessed Jul. 4, 2025].

[18] Drost, D., "Asparagus breeding: Future research needs for sustainable production", *Frontiers in Plant Sciences*, 14. 1148312. Mar. 2023.

[19] Eum, H.L., Yi, T.G., Hong, S.J., Park, N.-I., "Variations of Bioactive Compound Contents and Antioxidant Capacity of Asparagus Seedlings in 23 Varieties", *Horticultural Science and Technology*, 38(2). 291-302. Apr.2020.

[20] Redondo-Cuenca, A., García-Alonso, A., Rodríguez-Arcos, R., Castro, I., Alba, C., Rodríguez, J.M., Goñi, I., "Nutritional composition of green asparagus (*Asparagus officinalis* L.), edible part and by-products, and assessment of their effect on the growth of human gut-associated bacteria", *Food Research International*, 163. 112284. Jan. 2023.

[21] Goñi, I., García-Alonso, A., Alba, C., Rodríguez, J.M., Sánchez-Mata, M.C., Guillén-Bejarano, R., Redondo-Cuenca, A., "Composition and Functional Properties of the Edible Spear and By-Products from *Asparagus officinalis* L. and Their Potential Prebiotic Effect", *Foods*, 13(8). 1154. Apr. 2024.

[22] Słupski, J., Korus, A., Lisiewska, Z., Kmiecik, W., "Content of amino acids and the quality of protein in as-eaten green asparagus (*Asparagus officinalis* L.) products", *International Journal of Food Science and Technology*, 45(4). 733-739. Apr. 2010.

[23] Schwarzbach, A., Schreiner, M., Knorr, D., „Effect of cultivars and deep freeze storage on saponin content of white asparagus spears (*Asparagus officinalis* L.)", *European Food Research and Technology*, 222(1). 32-35. Aug. 2005.

[24] Slatnar, A., Mikulic-Petkovsek, M., Stampar, F., Veberic, R., Horvat, J., Jakse, M., Sircelj, H., "Game of Tones: sugars, organic acids, and phenolics in green and purple asparagus (*Asparagus officinalis* L.) cultivars", *Turkish Journal of Agriculture and Forestry*, 42(1).7. Sep.2017.

[25] Chen, X.H., Ma, L.H., Dong, Y.W., Song, H., Pu, Y., Zhou, Q.Y., "Evaluation of the differences in phenolic compounds and antioxidant activities of five green asparagus (*Asparagus officinalis* L.) cultivars", *Quality Assurance and Safety of Crops & Foods*, 9(4). 479–487. Oct. 2017.

[26] Kiliçgün, H., "Antioxidant Activity and Chemical Content of Infusions of *Asparagus* L. Plant in Different Concentrations", *Erzincan University Journal of Science and Technology*, 13(2). 803-810. Sep.2020.

[27] Guan, Y.J., Zhou, L.Y., Bi, J.F., Yi, J.Y., Li, S.R., "Evaluation of nutritive composition and antioxidant activity in different parts of green asparagus", *Science and Technology of Food Industry*, 5. 343-347. 2015.

[28] Gao, R., Li, G., Liu, P., Gao, L., Bi, J., Jiang, Y., Liu, H., Wang, Y., "The quality evaluation of 30 *Asparagus officinalis* L. varieties", *Food Science & Nutition*, 12. 2908-2916. Jan. 2024.

[29] Ku, Y.G., Bae, J.H., Namieśnik, J., Barasch, D., Nemirovski, A., Katrich, E., Gorinstein, S., "Detection of Bioactive Compounds in Organically and Conventionally Grown Asparagus Spears", Food Anal. Methods, 11. 309-318. Oct. 2018.

[30] Chileh Chelh, T., Rincon-Cervera, M.A., Gomez-Mercado, F., Lopez-Ruiz, R., Gallon-Bedoya, M., Ezzaitouni, M., Guil-Guerrero, J.L., "Wild *Asparagus* Shoots Constitute a Healthy Source of Bioactive Compounds", *Molecules*, 28. 5786. Jul. 2023.

[31] Mastropasqua, L., Tanzarella, P., Paciolla, C., "Effects of postharvest light spectra on quality and health-related parameters in green *Asparagus officinalis* L.", *Postharvest Biology and Technology*, 112. 143-151. Feb. 2016.

[32] Patel, D.K., Kumar, R., Prasad, S.K., Hemalatha, S., "Pharmacologically screened aphrodisiac plant-A review of current scientific literature". *Asian Pacific Journal of Tropical Biomedicine*, 1(1). S131–S138. Sep. 2011.

[33] Singh, R., Ali, A., Gupta, G., Semwal, A., Jeyabalan, G., "Some medicinal plants with aphrodisiac potential: A current status", *Journal of Acute Disease*, 2(3). 179-188. Sep. 2013.

[34] Thakur, M., Chauhan, N.S., Bhargava, S., Dixit, V.K., "A comparative study on aphrodisiac activity of some ayurvedic herbs in male albino rats", *Archives of Sexual Behavior*, 38(6). 1009-1015. Jan. 2009.

[35] Maeda, T., Kakuta, H., Sonada, T., Motoki, S., Ueno, R., Suzuki, T., Oosowa, K., "Antioxidation capacities of extracts from green, purple, and white asparagus spears related to polyphenol concentration", *HortScience*, 40. 1221-1224. Aug. 2005.

[36] Kumar, M.S., Udupa, A.L., Sammodavardhana, K., Rathnakar, U.P., Shvetha, U., Kodancha, G.P., "Acute toxicity and diuretic studies of the roots of *Asparagus racemosus* Willd in rats", West Indian Medical Journal, 59(1), 3-6. Jan. 2010.

[37] Pegiou, E., Mumm, R., Acharya, P., de Vos, R.C.H., Hall, R.D., "Green and White Asparagus (*Asparagus officinalis*): A Source of Developmental, Chemical and Urinary Intrigue", *Metabolites*, 10(1). 17. Dec. 2019.

[38] Zhao, J., Zhang, W., Zhu, X., Zhao, D., Wang, K., Wang, R., Qu, W., "The aqueous extract of *Asparagus officinalis* L. by-product exerts hypoglycaemic activity in streptozotocin-induced diabetic rats", *Journal of the Science of Food and Agriculture*, 91(11). 2095-2099. Aug. 2011.

[39] Zhu, X., Zhang, W., Zhao, J., Wang, J., Qu, W., "Hypolipidemic and hepatoprotective effects of ethanolic and aqueous extracts from *Asparagus officinalis* L. by products in mice fed a high-fat diet", *Journal of the Science of Food and Agriculture*, 90. 1129-1135. Mar. 2010.

[40] Luo, S., Zhou, L., Jiang, X., Xia, Y., Huang, L., Ling, R., Tang, S., Zou, Z., Chen, C., Qiu, J., "*Asparagus cochinchinensis* alleviates disturbances of lipid metabolism and gut microbiota in high-fat diet-induced obesity mice", Frontiers in Pharmacology, 13. 1015005. Oct. 2022.

[41] Kim, J.E., Park, J.W., Kang, M.J., Choi, H.J., Bae, S.J., Choi, Y.S., Lee, Y.J., Lee, H.S., Hong, J,T., Hwang, D.Y., "Anti-Inflammatory Response and Muscarinic Cholinergic Regulation during the Laxative Effect of *Asparagus cochinchinensis* in Loperamide-Induced Constipation of SD Rats", *International Journal of Molecular Sciences*, 20(4). 946. Feb. 2019.

[42] Anders, J.P.V., Keller, J.L., Smith, C.M., Hill, E.C., Housh, T.J., Schmidt, R.J., Johnson, G.O., "The Effects of *Asparagus Racemosus* Supplementation Plus 8 Weeks of Resistance Training on Muscular Strength and Endurance", *Journal of Functional Morphology and Kinesiology*, 5(1). 4. Jun. 2020.

[43] Olas, B., "A Review of the Pro-Health Activity of *Asparagus officinalis* L. and its Components", *Foods*, 13(2). 288. Jan. 2024.

[44] Srivastava, A., Ahmad, R., Srivastava, A.K., "Preparation, Sensory, and Nutritional Evaluation of Extruded Functional Food Products Using *Asparagus racemosus* (Shatavari)". *Cureus*, 17(2). e79593. Feb. 2025.

[45] Zhang, F., Chen, S., Zhang, J., Thakur, K., Battino, M., Cao, H., Farag, M.A., Xiao, J., Wei, Z., "Asparagus saponins: effective natural beneficial ingredient in functional foods, from preparation to applications", *Critical Reviews in Food Science and Nutrition*, 64(33). 12284-12302. Aug. 2023.

[46] Aktar, M.W., Sengupta, D., Chowdhury, A., "Impact of pesticides use in agriculture: their benefits and hazards", *Interdisciplinary Toxicology*, 2(1). 1-12. Jun. 2009.

[47] Oirdi, M.E., Yaseen, M., Farwa, U., Raza, M.A., Farhan, M., Sandhu, Z.A., Ali, F., Aatif, M., Khan, H.S., Nahvi, I., "Crops and people: the dangers and potential benefits of pesticides", *Cogent Food & Agriculture*, 10(1). 2334096. Apr. 2024.

[48] Ahmad, M.F., Ahmad, F.A., Alsayegh, A.A., Zeyaullah, M., AlShahrani, A.M., Muzammil, K., Saati, A.A., Wahab, S., Elbendary, E.Y., Kambal, N., Abdelrahman, M.H., Hussain, S., "Pesticides impacts on human health and the environment with their mechanisms of action and possible countermeasures", *Heliyon*, 10(7). e29128. Apr. 2024.

[49] Zhou, W., Li, M., Achal. V., "A comprehensive review on environmental and human health impacts of chemical pesticide usage", *Emerging Contaminants*, 11(1). 100410. Mar. 2025.

[50] European Commission, "Commission Regulation (EU) 2020/1085 of 23 July 2020 amending Annexes II and V to Regulation (EC) No 396/2005 of the European Parliament and of the Council as regards maximum residue levels for chlorpyrifos and chlorpyrifos-methyl in or on certain products (Text with EEA relevance)", *OJ L*, 239, 24.7.2020, 7-8.

[51] Saunders, M., Magnanti, B.L., Correia Carreira S., Yang, A., Alamo-Hernández, U., Riojas-Rodriguez, H., Calamandrei, G., Koppe, J.G., Krayer von Krauss, M., Keune, H., Bartonova, A., "Chlorpyrifos and neurodevelopmental effects: a literature review

and expert elicitation on research and policy", *Environmental Health*, 11(Suppl 1). S5. Jun.2012.

[52] Van Scoy, A.R., Yue, M., Deng, X., Tjeerdema, R.S., "Environmental Fate and Toxicology of Methomyl", *Reviews of Environmental Contamination and Toxicology*, 222. 93-109. Jan. 2012.

[53] Lin, Z., Zhang, W., Pang, S., Huang, Y., Mishra, S., Bhatt, P., Chen, S., "Current Approaches to and Future Perspectives on Methomyl Degradation in Contaminated Soil/Water Environments", *Molecules*, 25(3). 738. Feb. 2020.

[54] European Commission, "Commission Regulation (EU) 2023/1783 of 15 September 2023 amending Annexes II and V to Regulation (EC) No 396/2005 of the European Parliament and of the Council as regards maximum residue levels for denatonium benzoate, diuron, etoxazole, methomyl and teflubenzuron in or on certain products (Text with EEA relevance)". *OJ L*, 229, 18.9.2023, 63-88.

[55] Pang, S., Lin, Z., Zhang, Y., Zhang, W., Alansary, N., Mishra, S., Bhatt, P., Chen, S., "Insights into the Toxicity and Degradation Mechanisms of Imidacloprid Via Physicochemical and Microbial Approaches", *Toxics*, 8(3). 65. Sep. 2020.

[56] Wang, S., Han, X, Yu, T., Liu, Y., Zhang, H., Mao, H., Hu, C., Xu, X., „Isoprocarb causes neurotoxicity of zebrafish embryos through oxidative stress-induced apoptosis", *Ecotoxicology and Environmental Safety*, 242. 113870. Sep. 2022.

[57] Gu, H., Yuan, Y., Cai, M., Wang, D., Lv W., "Toxicity of isoprocarb to earthworms (*Eisenia fetida*): Oxidative stress, neurotoxicity, biochemical responses and detoxification mechanisms", *Environmental Pollution*, 290. 118038. Dec.2021

[58] Min, N., Park, H., Hong, T., An, G., Song, G., Lim, W., "Developmental toxicity of prometryn induces mitochondrial dysfunction, oxidative stress, and failure of organogenesis in zebrafish (*Danio rerio*)", *Journal of Hazardous Materials*, 443, Part A. 130202. Feb. 2023.

[59] Peng, J., Fan, R., Ren, Y., Yang, Y., Zhang, X., Wang, S., Mu, Y., Cheng, B., "Distribution and bioaccumulation of prometryn in simulated aquatic ecosystems", *Frontiers in Environmental Science*, 12. 1511658. Jan. 2025.

[60] Alengebawy, A., Abdelkhalek, S.T., Qureshi, S.R., Wang, M.-Q., "Heavy Metals and Pesticides Toxicity in Agricultural Soil and Plants: Ecological Risks and Human Health Implications", *Toxics*, 9(3). 42. Feb. 2021.

[61] Balali-Mood, M., Naseri, K., Tahergorabi, Z., Khazdair, M.R., Sadeghi, M., "Toxic Mechanisms of Five Heavy Metals: Mercury, Lead, Chromium, Cadmium, and Arsenic", *Frontiers in Pharmacology*, 12. 643972. Apr. 2021.

[62] Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B.B., Beeregowda, K.N., "Toxicity, mechanism and health effects of some heavy metals", *Interdisciplinary Toxicology*, 7(2). 60-72. Nov. 2015.

[63] Jomova, K., Alomar, S.Y., Nepovimova, E., Kuca, K., Valko, M., "Heavy metals: toxicity and human health effects", *Archives of Toxicology*, 99(1), 153-209. Nov. 2024.

[64] Martínez-Guijarro, R., Paches, M., Romero, I., Aguado, D., 2021, "Sources, Mobility, Reactivity, and Remediation of Heavy Metal(loid) Pollution: A Review", *Advances in Environmental and Engineering Research*, 2(4), 33. Dec.2021.

[65] Mitra, S., Chakraborty, A.J., Tareq, A.M., Emran, T.B., Nainu, F., Khusro, A., Idris, A.M., Khandaker, M.U., Osman, H., Alhumaydhi, F.A., Simal-Gandara, J., "Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity", *Journal of King Saud University - Science*, 34(3). 101865. Feb. 2022.

[66] Perrelli, M., Wu, R., Liu, D.J., Lucchini, R.G., Del Bosque-Plata, L., Vergare, M.J., Akhter, M.P., Ott, J., Gragnoli, C., "Heavy metals as risk factors for human diseases – a Bayesian network approach", *European Review for Medical and Pharmacological Sciences*, 26. 9275-9310. Dec. 2022.

[67] Roozbahani, M.M., Sobhanardakani, S., Karimi, H., Sorooshnia, R., "Natural and Anthropogenic Source of Heavy Metals Pollution in the Soil Samples of an Industrial Complex; a Case Study", Iranian Journal of Toxicology, 9. 1336-1341. Jan.2015.

[68] Sutkowska, K., Teper, L., Czech, T., Hulok, T., Olszak, M., Zogala, J., "Quality of Peri-Urban Soil Developed from Ore-Bearing Carbonates: Heavy Metal Levels and Source Apportionment Assessed Using Pollution Indices", *Minerals*, 10 (12). 1140. Dec.2020.

[69] European Commission, "Commission Regulation (EU) 2023/915 of 25 April 2023 on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006 (Text with EEA relevance)", *OJ L*, 119, 5.5.2023, 103-157.

[70] Biddau, R., Cidu, R., "Metals and Metalloids in Wild Asparagus at Uncontaminated and Mining-Contaminated Sites", *Journal of Environmental Quality*, 46(2). 320-329. Mar.-Apr.2017.

[71] Conversa, G., Miedico, O., Chiaravalle, A.E., Elia, A., "Heavy metal contents in green spears of asparagus (*Asparagus officinalis* L.) grown in Southern Italy: Variability among farms, genotypes and effect of soil mycorrhizal inoculation", *Scientia Horticulturae*, 256. 108559. Oct.2019.

[72] Xu, N., Zhang, H., Jia, J., Li, H., Zhu, Z., Fu, S., Wang, Y., „Assessment of Contents and Health Impacts of Four Metals in Chongming Asparagus— Geographical and Seasonal Aspects", *Foods*. 11, 624. Feb.2022.

[73] Zwolak, A., Sarzyńska, M., Szpyrka, E., Stawarczyk, K., "Sources of Soil Pollution by Heavy Metals and Their Accumulation in Vegetables: a Review", *Water, Air, & Soil Pollution*, 230. 164. Jul.2019.

[74] Denben, B., Sripinyowanich, S., Ruangthai, R., Phoemsapthawee, J., "Beneficial Effects of *Asparagus officinalis* Extract Supplementation on Muscle Mass and Strength following Resistance Training and Detraining in Healthy Males", *Sports*, 11(9). 175. Sep.2023.

[75] Porębska, A., Medicinal plants in nutricosmetics. *Aesthetic Cosmetology and Medicine*, 12(1). 11-15. Feb.2023.

[76] Tran, T.T.T., Ngo, L.H.N., Le, T.H.N., Ton, N.M.N., Le, T.T., Le, V.V.M., "High-Fiber Crackers Supplemented with Asparagus Hard-Stem: Impacts of Supplementation Ratios and Water Amounts in Cracker Recipe on the Product Quality", *Polish Journal of Food and Nutrition Sciences*, 74(2). 162-168. May.2024.

[77] Champati, B.B., Padhiari, B.M., Ray, A., Jena, S., Mohanty, S., Naik, P.K., Nayak, S., Panda, P.C., "Assessment of variation in Shatavarin IV content in *Asparagus racemosus* through HPTLC analysis and identification of elite germplasm from Eastern India", *Pharmacognosy Magazine*, 18. 836-843. Nov.2022.

[78] Creydt, M., Hudzik, D., Rurik, M., Kohlbacher, O., Fischer, M., "Food Authentication: Small-Molecule Profiling as a Tool for the Geographic Discrimination of German White Asparagus", *Journal of Agricultural and Food Chemistry*, 66(50). 13328-13339. Nov.2018.

[79] Richter, B., Gurk, S., Wagner, D., Bockmayr, M., Fischer, M., "Food authentication: Multi-elemental analysis of white asparagus for provenance discrimination", *Food Chemistry*, 286. 475-482. Jul.2019.

[80] Zannella, C., Carucci, F., Aversano, R., Prohaska, T., Vingiani, S., Carputo, D., Adamo, P., "Genetic and geochemical signatures to prevent frauds and counterfeit of high-quality asparagus and pistachio", *Food Chemistry*, 237. 545-552. Dec.2017.