

Article

Not peer-reviewed version

Assessing Dietary Exposure to Pesticides: Insights from Greek Potato Consumers

[Konstantinos B. Simoglou](#)^{*}, [Zisis Vryzas](#), [Emmanouil Roiditakis](#)^{*}

Posted Date: 21 October 2025

doi: 10.20944/preprints202510.1571.v1

Keywords: pesticide residues; consumer perception; dietary exposure; potatoes; Greece; food safety; latent profile analysis



Preprints.org is a free multidisciplinary platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This open access article is published under a Creative Commons CC BY 4.0 license, which permit the free download, distribution, and reuse, provided that the author and preprint are cited in any reuse.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Article

Assessing Dietary Exposure to Pesticides: Insights from Greek Potato Consumers

Konstantinos B. Simoglou^{1,2}, Zisis Vryzas³ and Emmanouil Roditakis^{2,4,*}

¹ Department of Quality and Phytosanitary Inspections, Rural Economy & Veterinary Medicine Directorate, Regional Unit of Drama, 66133 Drama, Greece

² Department of Agriculture, School of Agricultural Sciences, Hellenic Mediterranean University, Estavromenos, 71004 Heraklion, Greece

³ Pesticide Science Laboratory, School of Agriculture, Faculty of Agriculture, Forestry and Natural Environment, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece

⁴ Institute of Agri-Food and Life Sciences, Hellenic Mediterranean University Research Centre, 71410 Heraklion, Greece

* Correspondence: eroditakis@hmu.gr

Abstract

The study investigates Greek consumers' beliefs and their assessment of the risks associated with consuming potatoes contaminated with pesticide residues, aiming to understand the relationship between perceived risk and actual dietary exposure. A survey of 1,318 participants was conducted, employing latent profile analysis to identify two distinct consumer profiles: Concerned Consumers, who prioritize certified products and exhibit lower potato consumption, and Confident Consumers, who demonstrate higher consumption levels and lower risk perception. Data from the consumer survey and the two-category grouping were benchmarked against data from the Greek report from the monitoring of pesticide residues in food to estimate exposure against established toxicological reference values. The results indicate that pesticide residues in Greek potatoes remain significantly below established toxicological reference values, with mean exposures well within safety limits for both consumer groups. Despite the higher consumption among Confident Consumers, their exposure levels are still negligible. The findings highlight a disconnect between consumer perceptions of pesticide risk and actual exposure, suggesting that current agricultural practices are effective in safeguarding public health. This study underscores the importance of evidence-based risk communication to bridge the gap between consumer concerns and scientific reality, reinforcing the role of potatoes as a safe and essential food source.

Keywords: pesticide residues; consumer perception; dietary exposure; potatoes; Greece; food safety; latent profile analysis

1. Introduction

The potato (*Solanum tuberosum* L.) has played a crucial role in the human diet for thousands of years, originating in the Andes of South America and spreading across the globe. As the third most important food crop worldwide, following rice and wheat, the potato offers significant nutritional value, being rich in carbohydrates, vitamins (particularly C and B6), minerals, and dietary fiber [1]. Its consumption varies significantly: adults in developed countries consume on average 50-150 g daily, whereas in rural areas of Africa and the highlands of Latin America intake can reach 300-800 g/day, with important consequences for meeting population dietary requirements [2].

The potato is calorie dense and nutritious and can play an important role in food security – it can help low-income farmers and vulnerable consumers because most production is consumed locally rather than entering international trade [3,4]. Unlike major cereals, only a fraction of potato production reaches foreign markets; potato prices are typically determined by local production costs

rather than international market fluctuations. The potato also shows health promoting properties, including reported anti-inflammatory and anticancer effects, which strengthen its value for food security and nutrition [5,6].

Despite its nutritional value, potato consumption has declined in parts of the Western world [7,8,9,4], with table potato consumption frequency projected to decrease further [4,10]. Concurrently, cultivated area and production volume have fallen in several European regions, notably Greece [11,12] and parts of Eastern Europe [4], highlighting the need to promote the potato's nutritional, economic and environmental attributes [10,13].

The cultivation of potatoes has been dependent on the use of pesticides for a period exceeding a century. Intensified, concentrated agricultural production, undertaken on both small and large farms, has resulted in considerable and regionally variable pesticide utilization to manage a substantial, diverse pest complex [14]. Potato cultivation faces major challenges from *Leptinotarsa decemlineata* (Say), which damages foliage; *Phytophthora infestans* (Montagne) de Bary, responsible for tuber rotting; and *Phthorimaea operculella* (Zeller), which affects tuber quality. Effective agrochemical management is essential for sustainable production and profitable yields [15,16,17,18]. A plethora of studies have reported the presence of pesticide residues in potatoes, thereby prompting both scientific and regulatory debate. The most notable case was the withdrawal of chlorpyrifos authorizations under Commission Implementing Regulation (EU) 2020/18. Based on available data, EFSA developed MRL proposals and conducted a consumer risk assessment for chlorpyrifos residues in food commodities, including potato [19]. In a subsequent statement, EFSA (2019) [20] concluded that its human health assessment identified critical toxicological concerns and that the approval criteria for human health in Regulation (EC) No 1107/2009 were not satisfied, a finding that contributed to the European Commission's decision to revoke approval.

The regulatory scrutiny and revocation of chlorpyrifos demonstrate how scientific evidence on residues can trigger policy action; however, regulatory measures alone do not resolve public unease. Greek consumers have expressed significant concerns regarding the presence of pesticide residues in foodstuffs. Many have reported feelings of fear for their own and their families' health, despite acknowledging the role of pesticides in ensuring food security and contributing to the economy [21]. A correlation has been identified between a lack of awareness about maximum residue levels (MRLs) and increased anxiety about residues. A significant proportion of the population erroneously believes that residues are completely prohibited [22,23]. Simoglou et al. [24] further document a crisis of confidence in governance and strong public demands for greater transparency, showing that distrust of authorities and opaque information flows amplify residue related concerns. Analyses of consumer attitudes identify predictors of benefit–risk perceptions such as personal values, confidence in control and certification procedures, gender, and received information, indicating the need for targeted, transparent risk communication and more participatory governance in the agro-food system [21,24,22].

The evidence from prospective cohorts on dietary exposure to pesticides and long-term health implications is limited and inconsistent. Several large cohort analyses have not identified a clear association between high dietary pesticide intake and overall cancer incidence or major subtypes [25]. Furthermore, reviews have highlighted that the number of studies per outcome is insufficient to permit confident evidence grading [26,27]. Conversely, using nonnegative matrix factorization (NMF), Rebouillat et al. [28] identified an increased breast cancer risk in overweight and obese women linked to a component highly correlated to several common synthetic pesticides (chlorpyrifos, imazalil, malathion, thiabendazole), while a component reflecting lower synthetic pesticide exposure showed inverse associations. Rebouillat et al. [29] further reported a positive association between an NMF component representing high synthetic pesticide exposure and type 2 diabetes risk in the full cohort, and an inverse association for a low exposure component restricted to participants with high dietary quality.

Increasing fruit and vegetable intake by one serving per day provides substantially greater cancer prevention benefits than the cancer risks linked to pesticide residues [30,31,25]. However, observational evidence suggests that pesticide residues may modify other health effects of produce. Higher pesticide residue exposure has been associated with attenuated cardiovascular benefits [32]

and adverse reproductive outcomes [33,34]. Some studies indicate potential benefit from consuming organic produce for cancer outcomes [26], and analyses distinguishing low versus high pesticide residue produce report inverse associations of low residue intake with mortality but null associations for high residue intake [35]. Overall, population studies and risk assessments consistently find that benefits of fruit and vegetable consumption far outweigh pesticide related cancer risks, while residue related effects on cardiovascular, reproductive, and mortality outcomes warrant further consideration [30,31,25,33,34,32,26,35].

Baudry et al. [26] conclude that the evidence linking dietary exposure to pesticide residue and non-communicable diseases is limited and inconsistent. In the field of cancer research, three cohort studies have yielded equivocal results. Two studies have identified positive associations for specific sites or subgroups, while one study has yielded no significant findings, resulting in an overall low evidence level. Conversely, other outcomes, including T2D, CHD, and mortality, are based on single studies, which complicates the evaluation process. The review draws attention to several limitations, including residual confounding, exposure misclassification, short follow-up periods, limited generalizability beyond Western populations, and the challenges of randomized controlled trials. To establish stronger causal inferences, it is necessary to conduct prospective research incorporating quantitative exposure assessment, longer follow-up periods, diverse populations, biomarker data, new approach methodologies and analyses of chemical mixtures.

EFSA has performed retrospective probabilistic cumulative assessments and prioritization exercises on dietary pesticide residues. Assessments for acute neurotoxic and chronic thyroid effects (2014–2016) found exposures below regulatory concern, with no major change through 2018 [36,37,38]. A 2016–2018 probabilistic analysis of AChE inhibiting pesticides across ten populations likewise found exposures below the threshold of concern [39]. To make future cumulative assessments tractable, EFSA [40] implemented a two-step probabilistic prioritization that first removed roughly 80% of substances unlikely to contribute to cumulative risk and then reduced candidate organ system targets by about 70%; this process identified liver, kidney, male reproductive system and the hematopoietic system as the highest priority targets and judged the resulting risk estimates to be conservative (more likely to overestimate than underestimate).

In the present study, we estimated the dietary exposure of a sample of Greek adult consumers and latent subgroups derived from latent profile analysis to pesticide residues from the consumption of various potato preparations. We used HELLANS consumption data derived from this study (May 2024–April 2025; N = 1,318) and quantitative residue data from the national monitoring program [41]. We employed a deterministic approach based on measured residue data and compared the estimated daily intake with the safety reference (ADI). We included all detectable active substances (registered or not) reported in the 2023 monitoring program. The study was approved by the Research Ethics and Deontology Committee of the Hellenic Mediterranean University, and all necessary data protection measures were followed. The research questions are: (a) distribution of quantities and types of potatoes and potato products (fried, oven-baked, boiled, potato salad, moussaka, potato chips) consumed by different consumer groups per person in g/kg bw/day; (b) dietary exposure from potato consumption; and (c) whether this exposure poses a health risk.

2. Materials and Methods

2.1. Study Details

The primary data-collection instrument was an online questionnaire administered through the European Commission's EUSurvey platform – an official survey-management system for public-opinion research. The questionnaire was designed to document consumers' perceptions of food safety with respect to pesticide residues and to collect information on food consumption habits among adults permanently resident in Greece. The survey was conducted from May 2024 to April 2025 as part of the study "HELLANS 2024–2025" and produced 1,318 completed responses. Participants were recruited through email invitations, social media posts, website notices, and digital news outlets. Upon entering the online questionnaire, they were informed about their rights, the study's objectives, and the voluntary nature of participation, including the right to withdraw at any time without penalty. The process was entirely anonymous, with measures in place to ensure

confidentiality and data security in compliance with the EU General Data Protection Regulation. Participants were assured that their data would be anonymized and used solely for research purposes. The study protocol received ethical approval from the Hellenic Mediterranean University Ethics Committee, ensuring the integrity of the research. A contact email and researchers' names were provided for participants to ask questions or seek clarification, fostering trust and ensuring they felt comfortable and informed throughout the process.

The questionnaire was designed based on Simoglou and Roditakis [21] and Trichopoulou et al. [42]. It was divided into three sections: socio-demographic information, attitudes, and food consumption. It recorded various factors, including gender, age, weight and height, education attainment, place of residence, physical activity, occupation, family income, presence of underage children, smoking habits, pesticide use habits, leisure time, and vegetarianism. Additionally, the questionnaire included closed 5-point Likert scale questions to assess participants' perceptions and attitudes, with response levels ranging from 1 = strongly disagree to 5 = strongly agree. To further enrich our findings, the study incorporated open-ended questions aimed at gathering qualitative insights into consumer perceptions and views related to food safety and pesticide residues. This qualitative data were analyzed separately and published in a prior study, which explored themes concerning consumer attitudes and perceptions of food safety within the framework of food citizenship [24].

2.2. Food Consumption Data

The dietary intake was assessed through a 24-hour dietary recall (24-DR) per participant [42]. This method aims to capture the foods and amounts consumed by an individual on specific days. The quantity consumed was recorded through portion-size measurement aids (food pictures) that were organized in a digital library, which was inserted in the tool. Each picture represented specific portion size which was previously weighted and photographed in a stable presentation background (a plate, a spoon, and a fork). Portion sizes were used those applied by the US NHANES 2019-2020 study [43].

The 24-hour recall (24-DR) method is limited when zero intakes occur, since these often reflect episodic consumption. To address this limitation, a food propensity questionnaire (FPQ) was administered. The FPQ estimates the probability of consumption independently of reported amounts and these probability estimates are then combined with intake amounts to characterize the distribution of usual intake. The FPQ is a brief, non-quantitative food-frequency questionnaire that records consumption frequency but not portion sizes [44,42].

From the questionnaire data, we constructed a consumption database for fruits and vegetables, including potatoes. The current study focuses on potato consumption, estimating typical potato product consumption (fried, oven-baked, boiled, potato salad, moussaka, potato chips) by adapting the National Cancer Institute (NCI) method modified by Vilone et al. [45] for EFSA. Specifically, consumption probability was calculated using a logistic regression model with predictors including season, day of the week, gender, income, and covariates food consumption frequency and body weight. Typical consumption quantity for each food item was estimated by applying a generalized linear model with a gamma distribution, following Vilone et al. [45] methodology.

2.3. Linking Food Consumption and Residue Concentration Data

The EFSA Pesticide Residue Intake Model (PRIMo) version 3.1 was used to estimate dietary exposure of study participants to pesticide residues. PRIMo 3.1 is suitable for post marketing dietary risk assessment and can estimate both long term (chronic) and short term (acute) exposure arising from residues measured in monitoring programs [46]. Input data included mean residue concentrations by food commodity from the national pesticide residue monitoring program for 2023, which were the most recent, fully published and quality assured data available at the time of analysis, publicly available in the Zenodo repository for EC funded research [41], together with mean consumption and body weight distributions derived from our study. Negative samples were handled by substituting $LOQ/2$, representing an intermediate yet conservative approach compared with using LOQ or 0 , in line with standard practice for left censored residue data [46]. Chronic exposure analyses combined the probability of potato consumption (gr/kg bw/day) with mean residue

concentrations (mg/kg) to estimate intake. Estimated intakes were compared with the acceptable daily intake (ADI; mg/kg bw/day) for each active substance, obtained from the EU Pesticide Database [47]. For the proportion of potato in the moussaka composition, 20% was adopted according to Ritzoulis [48]. No processing factors were applied to maintain a conservative assumption that all residues present in the raw food will reach the end consumer, following Quijano et al. [49].

2.4. Identifying Latent Consumers Subgroups

Concurrently, we aimed to investigate the potential existence of latent subgroups with distinct characteristics influencing potato consumption, with possible variations in pesticide residue exposure. A principal components analysis (PCA) was first applied for dimensionality reduction and extraction of the main components summarizing the data to a smaller set of composite variables. We employed an eigenvalue threshold greater than 1 as the criterion for retaining principal components (PCs). Following oblique (promax) rotation, the rotated loadings revealed a significantly simplified PC loading pattern, with each variable loading on a single PC. In the final analysis, we retained only variables with loadings greater than or equal to 0.50. We assessed the PCA's adequacy using two key statistical tests: Kaiser-Meyer-Olkin (KMO) test, which uses values between 0 and 1 as a measure of sampling adequacy and Bartlett's test of sphericity, where a significant result indicates that at least some pairwise correlations among variables are not equal to zero [50]. McDonald's ω (omega) reliability coefficients of internal consistency for scale variables loading on a single principal component were calculated. To obtain a single measure for each PC, the variables loading on a single PC were combined using composite scores for further analysis [50].

Latent profile analysis (LPA) [51,52) was conducted using the tidyLPA R-module in jamovi 2.7.5 [53] to identify homogeneous participant groups based on principal components. Model selection considered multiple fit indices (AIC, BIC, SABIC), stability measures (entropy, BLRT), posterior classification probabilities (>0.80) and class sizes (>5% of the sample). The final two-class solution was selected by balancing model fit, class sizes, and substantive interpretability [54]. The two-class solution was preferred because it demonstrated satisfactory fit (significant BLRT vs. the 1 class model), acceptable class prevalence (>5%), high posterior assignment probabilities (0.79-0.95), and a theoretically meaningful interpretation (Concerned vs. Confident Consumers). As part of profile validation, bootstrap re-sampling has been performed to evaluate confidence intervals of the subgroup estimates [55]. Also, independent samples t tests were conducted to compare principal component means and chi square (χ^2) tests were used to assess differences in demographic characteristics between the two profiles. Results from both sets of analyses supported the distinctiveness of the profiles, thereby reinforcing the validity of the classification and providing a comprehensive characterization of the two latent groups.

To evaluate potential differences in dietary exposure to pesticide residues across consumer segments, the PRIMo 3.1 model was applied to a dataset containing body weights and typical consumption patterns for each latent profile.

The analyses were carried out using the open-source statistical analysis software jamovi 2.7.5 using the R programming language [53].

3. Results

3.1. Characteristics of Survey Participants

A total of 1,318 participants replied to the questionnaire, from all Greek Regions. The target population under investigation is defined as consumers of plant food, aged from 18 to over 65 years old, and residents of both urban and rural areas from all over Greece (Continental and the Islands). In Appendix A, Table A1, the sociodemographic characteristics of the survey participants are presented. Both genders were represented adequately (females 57.9%), as well as all age groups. Most subjects (35.8%) were living in the northern Greece, with 31.9% in the Central and 32.2% in the Southern Greece. Most participants had at least a high school educational level and were mainly civil servants (55.3%), private employees (17.2%), self-employed persons (10.8%), university students (6.8%), and farmers (1.9%). Additionally, several individual habits were recorded concerning free spare time, smoking, sports habits, and vegetarian attitude (Appendix A, Table A1).

3.2. Analysis of Participants' Attitudes and Perceptions

This section presents the findings related to participants' views and perceptions regarding pesticide use, highlighting the key factors that shape their attitudes. The analysis aims to provide insights into how beliefs about food safety and environmental concerns influence consumer behavior, as revealed through the data collected.

3.2.1. Principal Components Underlying the Participants' Attitudes

The results of the principal components analysis (PCA) provide insights into the relationships among the initial variables related to beliefs about food safety and the consumption of fruits and vegetables. The analysis identified several principal components (Appendix A, Table A2): The first component, SPS (Specialized Sources), emphasizes specialized sources of information, with high loadings for official websites, public agency bulletins, and specialized journals, indicating their significant role in consumer education. The second component, PAG (Professional and Advocacy Guidance), highlights the importance of dietitians, consumer organizations, and health professionals in shaping consumer beliefs and behaviors regarding food safety and nutrition. The third component, POC (Potato Consumption), pertains to potato consumption, with strong associations with various forms of potato dishes, such as moussaka, potato salad etc., reflecting participants' preferences. The fourth component, GES (General Sources), addresses general sources of information, including television, radio, and print media, which also play a significant role in shaping consumer perceptions. The fifth component, FVC (Fruit and Vegetable Consumption), relates to the consumption of fruits and vegetables, with substantial loadings for both fresh and processed varieties, underscoring their importance in participants' diets. The sixth component, CPD (Certified Products Consumption), captures the consumption of certified products, indicating a strong consumer trust in certified and organic products, as well as a belief in the safety of pesticide application. The seventh component, PIC (Pesticide Confidence), focuses on beliefs regarding pesticide safety, with high loadings for perceptions that proper pesticide application ensures consumer safety and that the benefits of pesticides outweigh their risks. The total explained variance from the principal components reaches 63.33%, with the first component accounting for 12.24% of the variance. Scale Reliability indices (McDonald's ω) range from 0.66 to 0.82, indicating good scale reliability. Additionally, Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy test confirm the appropriateness of the data for PCA.

3.2.2. Latent Profile Analysis

The selected 2 class solution (LogLik = -14,728.397) produced AIC = 29,522.795, BIC = 29,693.862, and sample size adjusted BIC = 29,589.037. The BLRT comparing the 2 versus 1 class model was significant (BLRT = 1,190.629, $p = 0.010$), supporting the 2-class solution. Despite adequate class sizes, with estimated proportions of 30.6% and 69.4%, and acceptable posterior probabilities ranging from 0.793 to 0.947, the entropy value of 0.627 suggests a reasonable level of class separation, albeit with some classification uncertainty; therefore, model interpretability was used alongside fit indices to justify the final solution. The two latent profiles were theoretically interpretable based on their principal components differences. Welch's t-tests comparing profile means showed significant and directionally consistent differences on most components (Table 1): PIC (Pesticide confidence attitude); CPD (Certified products consumption); FVC (Fruit/vegetable consumption); GES (General sources of information); POC (Potato consumption habit). Two components did not differ between profiles (PAG: Professional & advocacy guidance; SPS: Specialized sources of information).

Also, chi-squared tests revealed significant demographic characteristics, such as age, gender, education, profession, family income etc. (Table 2). These differences provide substantive support for distinct, meaningful profiles (e.g., one profile characterized by higher pesticide concern, higher fruit/vegetable consumption and greater certified product consumption, the other by greater pesticide confidence and different potato consumption habits), strengthening the decision to retain the 2-class solution despite moderate entropy.

Table 1. Characterization of perceptions between two classes of respondents as they were identified by the LPA on the basis of principal components (Independent Samples t-Test: Class 1, N = 915, “Concerned consumers”; Class 2, N = 403, “Confident consumers”).

Principal components	Welch's t statistic	df	p
PIC: Pesticide confidence attitude	- 6.421	790.920	< 0.001
CPD: Certified products consumption	4.873	726.342	< 0.001
FVC: Fruit/vegetable consumption	16.660	554.772	< 0.001
GES: General sources of information	3.839	728.354	< 0.001
POC: Potato consumption habit	- 7.242	427.739	< 0.001
PAG: Professional & advocacy guidance	1.325	687.589	0.186
SPS: Specialized sources of information	0.168	746.951	0.866

Table 2. Sociodemographic characterization of the two obtained classes of respondents.

Background variables	Class 1 (N = 915)	Class 2 (N = 403)		Chi-Squared Test
	“Concerned consumers”	“Confident consumers”		
Gender	Male	36.4% (-6.3) (1)	55.1% (6.3)	X ² = 40.1; df = 1;
	Female	63.6% (6.3)	44.9% (- 6.3)	p < 0.001
Age	18 - 44	27.1% (- 2.0)	32.5% (2.0)	X ² = 4.0; df = 1;
	≥ 45	72.9% (2.0)	67.5% (- 2.0)	p = 0.046
Education	Secondary education	13.1 % (- 3.8)	21.3% (3.8)	X ² = 14.4; df = 1;
	Higher education	86.9 % (3.8)	78.7 % (- 3.8)	p < 0.001
Foodborne illnesses outweigh pesticide risks	Not in favour	78.1% (3.3)	69.7% (- 3.3)	X ² = 10.7; df = 1;
	In favour	21.9% (- 3.3)	30.3% (3.3)	p < 0.001
Profession	Civil servants	59.3% (4.4)	46.2 % (- 4.4)	X ² = 26.9; df = 6;
	Farmers	1.6% (- 1.0)	2.5 % (1.0)	p < 0.001
	Private employees	14.6% (- 3.7)	23.1 % (3.7)	
	Retired	4.3% (- 1.1)	5.7% (1.1)	
	Self-employed	10.8% (0.1)	10.7 % (0.1)	
	Unemployed	3.5% (0.4)	3.0 % (- 0.4)	
	University students	5.5% (- 2.1)	8.9% (2.1)	
Pesticide residues concern	No	2.4% (- 11.8)	21.8% (11.8)	X ² = 138.1; df = 1;
	Yes	97.6% (11.8)	78.2% (- 11.8)	p < 0.001
Family income	0 - 10,000 €	7.4% (- 3.3)	13.2% (3.3)	X ² = 17.3; df = 2;

	10,001 - 20,000 €	36.3% (- 1.6)	40.9% (1.6)	$p < 0.001$
	> 20,001 €	56.3% (3.5)	45.9% (- 3.5)	
Avoidance of perceived contaminated food	No	25.5% (- 7.4)	46.2% (7.4)	$X^2 = 55.2; df = 1;$
	Yes	74.5% (7.4)	53.8% (- 7.4)	$p < 0.001$
Physical activity	No	38.0% (- 4.2)	50.4% (4.2)	$X^2 = 17.5; df = 1;$
	Yes	62.0 % (4.2)	49.6 % (- 4.2)	$p = 0.001$

¹ Adjusted Pearson residuals (in brackets) > +2.0 denote significantly more cases than expected; residuals < -2.0 denote significantly fewer.

3.2.3. Latent Profiles Descriptions

Group 1: Concerned Consumers (LPA1)

The Concerned Consumers group (N=915) is characterized by a strong awareness and apprehension regarding pesticide use in food production. This group prioritizes the consumption of certified products (CPD), reflecting their commitment to food safety and quality. Moreover, they exhibit a high level of fruit and vegetable consumption (FVC), which underscores their preference for a healthy diet rich in natural foods. Interestingly, this group shows a lower tendency towards potato consumption habits (POC), suggesting that they may perceive potatoes as less healthy or potentially more problematic due to pesticide concerns. Their reliance on general sources of information (GES) further indicates a desire to stay informed about food safety issues, although they may not seek specialized knowledge more than Group 2. Demographically, this group is predominantly composed of females (63.6%), which is significantly higher compared to the Confident Consumers group. They tend to be older, with 72.9% of participants aged 45 and above, which is proportionally higher than expected by null hypothesis. Educationally, the majority hold higher education degrees (86.9%), which may contribute to their heightened awareness of food safety issues. Professionally, they are largely civil servants (59.3%), suggesting a stable professional background that may influence their consumption choices. A significant majority (97.6%) express concern about pesticide residues, indicating a strong belief that these residues pose a health risk. This concern is further reflected in their dietary habits, as 74.5% actively avoid perceived contaminated food, which is considerably higher than their counterparts. Additionally, they engage in physical activity (62.0%), which aligns with their health-conscious attitudes, although they may not seek professional/advocacy guidance on food safety issues more than Group 2.

Group 2: Confident Consumers (LPA2)

In contrast, the Confident Consumers group (N=403) reports comparatively lower concern about food safety and pesticide use. Their positive attitudes towards pesticide confidence (PIC) reveal a sense of assurance in the safety of the foods they consume. While they may consume fewer certified products (CPD) compared to the Concerned Consumers, their dietary choices reflect a broader acceptance of various food options. This group tends to have higher potato consumption habits (POC), indicating a willingness to include this staple in their diet without significant concern for pesticide residues. They rely less on general sources of information (GES), suggesting that they are less influenced by external advice regarding food safety. Demographically, this group has a higher proportion of males (55.1%), which is significantly higher than in the Concerned Consumers group. They also have a younger demographic profile, with 32.5% aged 18 to 44, which is proportionally higher compared to the older participants in the other group. They are more diverse in terms of educational background. Professionally, this group includes a notable percentage of private employees (23.1%) and university students (8.9%), indicating a broader range of occupations. They show a lower level of concern regarding pesticide residues, with 78.2% expressing worry, proportionally lower than expected by null hypothesis, which is significantly lower than the Concerned Consumers. Additionally, a significantly higher percentage (30.3%) in this group believes that foodborne illnesses outweigh the risks associated with pesticide residues, reflecting their more relaxed approach to concerns about agrochemicals. Their dietary habits reflect a greater acceptance

of various food options, as evidenced by a higher tendency to consume potatoes. Additionally, 46.2% do not actively avoid perceived contaminated food, reflecting less proactive food-safety behavior. This group also has a lower rate of physical activity (49.6%), which may also influence their overall health outlook.

3.3. Estimation of Exposure and Risk Assessment

This section presents the results of the estimated dietary exposure to pesticide residues and the corresponding risk assessment. The findings aim to evaluate the safety of pesticide consumption through potato intake, providing insights into the levels of exposure relative to established regulatory standards.

Table 3 summarizes the findings related to average potato consumption and mean body weights within the HELLANS 2024–2025 study. It includes data for the entire cohort of adult participants, and two latent profile subgroups, providing a comparative view of consumption patterns. Estimated mean consumption was 1.22 g/kg bw/day for entire sample, 0.74 g/kg bw/day for LPA1 and 2.30 g/kg bw/day for LPA2. Bootstrap resampling (5000 iterations, bias-corrected accelerated) produced consistent coefficient estimates and narrow 95% confidence intervals (intercept = 0.741, 95% CI [0.669–0.813], $p < 0.001$); membership effect = 1.554, 95% CI [1.383–1.755], $p < 0.001$); the reported bootstrap bias values were negligible (≈ 0.000), supporting the stability of the profile-level estimates.

Table 3. Summary statistics of potato consumption (g/kg body weight/day) - overall sample and LPA subgroups (HELLANS 2024–2025).

Sample groups		N	Mean body weight (kg)	Mean consumption (g/bw/day)	SD	IQR	Percentiles		
							50th	95th	99th
HELLANS (2024-2025)	Adults - overall study sample	1318	78.7	1.216	1.321	1.162	0.856	3.159	6.779
HELLANS (2024-2025) - LPA1	Adults – latent profile subgroup No1	915	77.9	0.741	0.469	0.706	0.650	1.648	1.921
HELLANS (2024-2025) - LPA2	Adults – latent profile subgroup No2	403	80.6	2.296	1.879	1.501	1.997	5.587	9.689

Table A3 (Appendix A) shows the results of the National monitoring program (2023). Overall, the percentage of positive samples was notably low, with detections ranging from 0.4% to 3.9% across various pesticides. Among the detected residues, the highest mean concentration was observed for mancozeb at 0.114 mg/kg, while the lowest was recorded for metalaxyl at 0.015 mg/kg. Conversely, most samples exhibited non-detects, with percentages ranging from 96.1% to 99.6%, indicating a predominant absence of pesticide residues in the analyzed samples. Furthermore, in terms of average residue concentration across the sample set, most pesticides demonstrated stable levels, largely remaining at 0.005 mg/kg.

Table A4 (Appendix A) shows the average dietary exposure to several pesticide residues due to consumption of potato. Using the EFSA Pesticide Residue Intake Model (PRIMo) ver. 3.1, we estimated chronic exposure by combining 2023 national monitoring mean residue concentrations, with consumption and body-weight distributions derived from the present study; estimated intakes were compared with the acceptable daily intake (ADI) values for each active substance. In the HELLANS 2024–2025, estimated dietary intakes for all examined active substances were substantially below their respective acceptable daily intakes (ADIs). Percentages of ADI across substances and groups ranged from approximately 0.00% to 1.72%, with the largest single contribution observed for fenamiphos in the HELLANS LPA2 subgroup (1.72% of ADI). Population-level point estimates for

individual compounds in the entire HELLANS sample were uniformly low (typically $\leq 0.91\%$ of ADI), and the aggregated Hazard Index values indicate minimal cumulative exposure (entire HELLANS = 0.014; LPA2 = 0.027; LPA1 = 0.009).

The two latent profile analysis subgroups differed quantitatively but not qualitatively: LPA2 consistently exhibited modestly higher estimated intakes across compounds than LPA1, yet these differences remained negligible relative to toxicological reference values and do not alter the risk characterization. Overall, the results demonstrate that dietary exposure to the assessed pesticides in the HELLANS 2024-2025 study – including both latent subgroups – is far below regulatory ADIs and does not indicate concern for chronic health effects under the assumptions and methods applied.

4. Discussion

The present study examined Greek consumers' beliefs and consumption patterns regarding potato intake and pesticide residues, combining survey-based attitudinal profiling with dietary exposure assessment (N = 1,318). Overall, two distinct consumer profiles emerged – one characterized by heightened concern and preference for certified products and higher fruit/vegetable intake, the other by greater confidence in food safety and higher potato consumption – while quantitative exposure estimates from potato consumption were uniformly far below established toxicological reference values (ADIs). These findings place consumer perceptions of pesticide risk in the context of measured exposure and highlight implications for risk communication and policy.

Three complementary data streams were integrated in the present study – sociodemographic profiling, psychometric segmentation, and quantitative dietary exposure assessment – to evaluate the health risk posed by pesticide residues in potatoes consumed by Greek adults (N = 1,318). The sample was 57.9 % female, predominantly middle aged (40.9 % aged 45–54 y), and highly educated (75.7 % holding university qualifications). Geographically The sample included participants from Northern (35.8 %), Central (31.9 %) and Southern Greece (32.2 %), with 77.5 % residing in urban areas. Compared with the 2021 ELSTAT census (51.1 % females; 33.2 % secondary and 21.1 % tertiary education) [56], the cohort shows a modest gender skew and a markedly higher proportion of university educated participants, suggesting that findings should be generalized to general Greek population with appropriate caution.

The modest over-representation of women and the higher share of university-educated respondents compared with the 2021 ELSTAT census constrain the external validity of overall prevalence estimates. To mitigate this, we performed a latent profile analysis (LPA) [51,52], which identified two psychometrically distinct profiles: “Concerned” (LPA1) and “Confident” (LPA2) consumers. We report exposure and risk metrics separately by profile because (i) LPA captures intra-sample heterogeneity [57], (ii) the profiles differ significantly on age, gender, education, and consumption behaviors, and (iii) profile-specific results yield different exposure patterns: LPA1 (i.e. older, predominantly female, higher education) shows mean exposures well below the ADI, while LPA2 (i.e. younger, more male) shows higher mean exposures though still within safety limits. By stratifying results on empirically derived latent profiles and reporting profile-specific uncertainty, we more directly model intra-sample heterogeneity [57] rather than averaging over demographically skewed observations. This person-centered approach has been shown to produce more relevant subgroup estimates for inference and to yield latent classes that are more representative of the underlying population [51,58]. Profile-level confidence intervals and bootstrap-based uncertainty estimates clarified the precision of our analysis and highlighted potential biases, thereby significantly enhancing the interpretability of the results [55].

Latent profile analysis identified two distinct consumer groups, reflecting the underlying demographic and behavioral differences. The concerned consumers (LPA1; n = 915) were older, predominantly highly educated women who expressed a strong perception of the risks associated with pesticides. They preferred certified products and consumed relatively small amounts of potatoes (mean $0.74 \text{ g kg}^{-1} \text{ bw day}^{-1}$; 99th percentile $1.92 \text{ g kg}^{-1} \text{ bw day}^{-1}$). The Confident Consumers group (LPA2; n = 403) was younger and more gender-balanced, though male-dominated, with a modestly higher share of secondary-educated members and fewer with higher education. They showed lower risk perception and relied less on certification (Table 2). They also reported substantially higher

potato consumption (mean 2.30 g kg⁻¹ bw day⁻¹; 99th percentile 9.69 g kg⁻¹ bw day⁻¹). These behavioral differences were reflected in the principal components structure, with the “Pesticide Confidence” component being significantly higher on LPA2 and “Certified Product” and “Fruit/Vegetable Consumption” components being significantly higher on LPA1 (Table 1).

The dietary exposure results (Table A4) show that, pesticide residues in Greek potatoes (National monitoring program 2023) remain far below the toxicological safety limits, both for the average consumer and for the most extreme (99th percentile) intake scenarios. Across the entire HELLANS 2024 2025 sample the mean intakes of all pesticides were ≤0.91% of their respective acceptable daily intakes (ADIs); the highest mean contribution came from fenamiphos (0.91% of ADI). When the 99th percentile consumption is considered, the largest relative exposure again belongs to fenamiphos (5.08% of ADI), followed by lambda-cyhalothrin (1.36 %) and fosthiazate (1.02%). Every other pesticide stayed ≤0.18% of its ADI even under this worst-case consumption.

Stratifying the data by the two latent profile groups reveals a consistent pattern. The Concerned Consumers (LPA1) exhibit mean exposures that are lower than those of the overall cohort (e.g., fenamiphos 0.56% of ADI, lambda-cyhalothrin 0.15% of ADI), and 99th percentile values are modest (fenamiphos 1.44% of ADI, lambda-cyhalothrin 0.38% of ADI). Confident Consumers (LPA2) show higher mean intakes (fenamiphos 1.72% of ADI, lambda-cyhalothrin 0.46% of ADI) and higher 99th percentile values (fenamiphos 7.27% of ADI, lambda-cyhalothrin 1.94% of ADI), yet these worst-case figures remain well under the ADI threshold.

The cumulative Hazard Index (HI), which is the sum of each substance’s exposure expressed as a fraction of its acceptable daily intake (ADI), corroborates the low-risk picture: the overall HI is 0.014, 0.009 for LPA1 and 0.027 for LPA2; at the 99th percentile the indices rise to 0.080, 0.023 and 0.114 respectively – still an order of magnitude below the critical value of 1 that would indicate a potential health concern [59]. Consequently, despite the Confident group’s higher potato consumption, absolute pesticide intakes stay comfortably within regulatory safety margins, and the Concerned group’s lower intake further reduces an already negligible exposure.

These findings demonstrate that the divergent attitudes captured by psychometric profiling do not translate into meaningful differences in toxicological risk. Both consumer segments are exposed to pesticide residues at levels far below ADIs, supporting the conclusion that current pesticide practices on Greek potatoes are adequately protective, and that risk communication efforts can focus on reassuring consumers rather than on mitigating a real health threat.

The gap between perceived risk (heterogeneous across LPA subgroups, but collectively high within the entire cohort) and actual toxicological risk illuminates the profound disconnect between consumer perception and scientific evidence. This discrepancy may stem from various factors, including the public's heightened sensitivity to chemical dangers regardless of exposure level, as demonstrated by Slovic et al. [60]. While risk perception varies between LPA1 (showing higher concern) and LPA2 (displaying lower concern), the overarching sentiment across the study population reflects a heightened sense of concern about pesticide exposure. Previous research has shown that pesticide residues in food are a high-priority concern for Greek consumers, with a direct link to health issues [21]. They ranked pesticide residues as the most important food safety concern, followed by animal diseases and veterinary pharmaceutical residues in meat [61]. However, the empirical data clearly show these concerns are not supported by the evidence, consistent with prior work demonstrating that consumer perceptions of food safety often diverge from measured risk [62]. For Concerned Consumers, the data provides concrete reassurance: even their most extreme consumption scenarios remain substantially below the Acceptable Daily Intake (ADI), effectively neutralizing potential health apprehensions. Similarly, for Confident Consumers, the scientific findings offer a nuanced perspective: despite higher potato consumption, their pesticide-residue exposure remains negligibly low and well within established safety parameters. This targeted, evidence-based communication approach can strategically bridge the psychological divide between consumer perceptions and scientific reality, promoting a more rational and informed understanding of food safety [60,63,62].

The subgroup analysis of the LPA2 data reveals that the 99th percentile exposure consistently remains significantly below established safety thresholds across potato samples. This finding

indicates that current agricultural practices and regulatory frameworks effectively safeguard public health across various regions and production systems. Consequently, these results imply that regulatory efforts should focus on sustaining the existing standards for potato safety.

These findings are consistent with previous regulatory monitoring in the European Union. The 2021-2023 monitoring programs indicate that estimated dietary exposure – both acute and chronic – to individual pesticide residues with available health-based guidance values (HBGVs) is low for most assessed EU subpopulation groups [64]. Retrospective probabilistic cumulative assessments from 2014 to 2016 showed that exposures related to acute neurotoxic and chronic thyroid effects remained below regulatory concern, with no significant changes through 2018 [36,37,38]. Furthermore, the assessment of craniofacial alterations [40] confirmed that established regulatory thresholds were not exceeded.

Studies indicate that the cumulative risk from pesticide residues in potatoes is low. Reis et al. [30] reported that insecticide residues in potatoes were below the EU's maximum residue limits, posing no health concerns. Similarly, Jensen et al. [65] found that the Hazard Index for chronic dietary exposure to monitored pesticides in Denmark, including potatoes, was below 1 for both children and adults, indicating no risk of adverse health effects. Witzak et al. [66] assessed organophosphorus pesticides in fruits and vegetables, including potatoes, available in Poland, and found residue levels significantly below maximum residue limits (MRLs). Their evaluation revealed estimated Hazard Quotients within safe limits, suggesting minimal risk to human health from organophosphorus pesticide exposure. Additionally, Quijano et al. [49] studied chronic cumulative exposure to organophosphorus, carbamate, and pyrethroid pesticides in Valencia, Spain, through the consumption of fruits and vegetables, including potatoes. They found that the chronic cumulative intake of analyzed pesticide residues was relatively low compared to the Acceptable Daily Intake (ADI), indicating no expected long-term consumer risk.

Effective communication regarding these findings should be evidence-based and nuanced. It is essential to emphasize the substantial safety margins associated with the Concerned profile while confirming safe exposure levels for the Confident profile [61,63,62]. The potato constitutes a pivotal component of global food security, furnishing substantial nutritional value at a relatively low cost, thereby addressing dietary requirements in vulnerable populations worldwide [1,4,3]. Our findings corroborate that potato consumption poses no appreciable chronic toxicological risk, with pesticide residues consistently below permissible thresholds, thereby reinforcing its status as a fundamental food source.

This study is subject to certain limitation related to the available data. The online questionnaire may introduce selection bias by excluding individuals with limited digital literacy, reducing representativeness. The sample is overrepresented by women and highly educated participants, limiting generalizability to the Greek population. Dietary assessment via 24-hour recalls is subject to recall bias and poorly captures episodic consumption; although the food propensity questionnaire (FPQ) and linear regression partly mitigate this, the FPQs lack portion-size information. Pesticide-residue analysis used a single year of national monitoring data, which may not reflect seasonal or interannual variability; assuming residues in raw foods reach consumers unchanged (no processing factors) likely overestimates exposure. Results from latent profile analysis (LPA) depend on model specification, and alternative models could produce different class solutions, the chosen model prioritized interpretability.

5. Conclusions

The present study provides significant insights into Greek consumers' beliefs and consumption patterns regarding potato intake and pesticide residues. Two distinct consumer profiles were identified: the Concerned Consumers, characterized by heightened awareness and preference for certified products, and the Confident Consumers, who exhibit greater confidence in food safety and higher potato consumption. Despite the differences in risk perception and consumption behaviors, both groups demonstrated pesticide exposure levels well below established toxicological reference values (ADIs), indicating that current agricultural practices effectively safeguard public health.

The findings underscore a notable disconnect between consumer perceptions of pesticide risk and actual dietary exposure, with most participants expressing concern despite empirical evidence showing negligible health risks. This gap highlights the need for targeted risk communication strategies that reassure consumers about the safety of potato consumption while addressing their concerns.

Moreover, the study's methodological approach, integrating sociodemographic profiling, psychometric segmentation, and quantitative dietary exposure assessment, enhances the robustness of the findings. The results suggest that regulatory efforts should focus on maintaining existing safety standards for potatoes, as current practices are sufficient to protect public health. Overall, the study reinforces the role of potatoes as a vital component of food security, providing essential nutritional value without posing significant toxicological risks.

Author Contributions: Conceptualization, K.B.S. and E.R.; methodology, K.B.S.; validation, K.B.S.; formal analysis, K.B.S.; investigation, K.B.S.; data curation, K.B.S.; writing—original draft preparation, K.B.S.; writing—review and editing, E.R. and Z.V.; visualization, K.B.S.; supervision, E.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Consumption data is unavailable due to restrictions imposed by the Research Ethics and Deontology Committee.

Acknowledgments: The authors would like to express their gratitude to Ms. Paraskevi Skarpa for her invaluable advice.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Sociodemographic characteristics of the respondents (N = 1,318).

Demographic variables		Frequency	Percentage
Gender	Female	763	57.9%
	Male	555	42.1%
Age	18 – 24	96	7.3%
	25 – 34	89	6.8%
	35 – 44	194	14.7%
	45 – 54	539	40.9%
	55 – 64	338	25.6%
	≥ 65	62	4.7%
Educational background	Less than high school	3	0.2%
	High school – Technical education	203	15.4%
	Bachelor's degree	478	36.3%
	Master's degree	519	39.4%
	Doctoral degree	115	8.7%
Residential geographical area	Northern Greece	472	35.8%
	Central Greece	421	31.9%
	Southern Greece	425	32.2%

Population of place of residence	Less than 10,000 inhabitants (rural)	297	22.5%
	More than 10,000 inhabitants (urban)	1021	77.5%
Underage children in the family	No	760	57.7%
	Yes	558	42.3%
Plenty of spare time	No	571	43.3%
	Yes	747	56.7%
Smoking habits	No	1042	79.1%
	Yes	276	20.9%
Vegetarian by choice	No	1266	96.1%
	Yes	52	3.9%
Physical activity habits	Never	243	13.2%
	Occasionally (< 1–2 times/month)	1207	65.4%
	Often (3–4 times/month)	396	21.4%
	Habitually (> 2 times/week)		
Professional or amateur pesticide users	No	919	69.7%
	Yes	399	30.3%
Occupation	Civil servants	729	55.3%
	Private employees	227	17.2%
	Self-employed	142	10.8%
	Farmers	25	1.9%
	Unemployed	44	3.3%
	University students	89	6.8%
	Retired	62	4.7%

Table A2. Results of the principal component analysis

Original variables	Principal components							Uniqueness ⁽³⁾
	SPS	PAG	POC	GES	FVC	CPD	PIC	
	Specialized sources	Professional & advocacy guidance	Potato consumption	General sources	Fruit/vegetable consumption	Certified products	Pesticide confidence	
Official Websites	0.825							0.332
Public Agency Bulletins	0.807							0.320
Specialized Journals (Agriculture, Nutrition, etc.)	0.784							0.385
News Websites	0.702							0.372

Agronomists	0.525							0.378
Dietitian– Nutritionist		0.771						0.426
Consumer Organizations		0.752						0.352
Environmental– Ecological Organizations		0.750						0.395
Health Professionals		0.696						0.393
Moussaka Consumption			0.867					0.238
Potato Salad Consumption			0.781					0.371
Boiled Potato Consumption			0.750					0.422
Baked Potato Consumption			0.708					0.475
Television–Radio Online			0.810					0.335
Newspapers Newspapers– Magazines			0.755					0.356
Vegetable Consumption (Fresh/Processed)			0.673					0.411
Fruit Consumption (Fresh/Processed)				0.815				0.349
Adherence to Traditional Greek Cuisine					0.805			0.362
Consumption of Certified Products Certified Origin Products						0.874		0.276
Consumption Organic Fruits and Vegetables						0.857		0.280
Consumption Proper Pesticide Application Ensures Consumer Safety							0.529	0.501
Pesticide Benefits Outweigh Risks							0.854	0.283
Sum of the squared loadings	2.94	2.56	2.45	1.99	1.84	1.82	1.62	
Scale reliability (McDonald's ω)	0.82	0.78	0.79	0.79	0.70	0.70	0.66	
Explained variance %	12.24	10.65	10.19	8.27	7.66	7.59	6.73	
Cumulative variance %	12.24	22.89	33.08	41.35	49.01	56.6	63.33	

Bartlett's Test of Sphericity	$\chi^2 = 9,971.9; df = 276; p < 0.001$
KMO Measure of Sampling Adequacy test	0.765

Table A3. Pesticide residue analysis summary in potatoes samples (N=231) from the National monitoring program (2023)

Pesticide	ADI mg/kg bw/day	LOQ mg/kg	Positive samples (% in brackets)	Mean positive residues mg/kg	Non detects (% in brackets)	Mean non- detects residues (LOQ/2) mg/kg	Average residue concentration mg/kg
imidacloprid	0.060*	0.01	8 (3.5%)	0.024	223 (96.5%)	0.005	0.006
flutolanil	0.090*	0.01	2 (0.9%)	0.021	229 (99.1%)	0.005	0.005
propamocarb	0.290*	0.01	9 (3.9%)	0.017	222 (96.1%)	0.005	0.005
dimethomorph	0.050*	0.01	4 (1.7%)	0.016	227 (98.3%)	0.005	0.005
fenamiphos	0.001*	0.01	1 (0.4%)	0.022	230 (99.6%)	0.005	0.005
fluaziphop-p	0.010*	0.01	3 (1.3%)	0.078	228 (98.7%)	0.005	0.006
fluopicolide	0.080*	0.01	3 (1.3%)	0.016	228 (98.7%)	0.005	0.005
fluopyram	0.012*	0.01	7 (3.0%)	0.017	224 (97.0%)	0.005	0.005
fosthiazate	0.004*	0.01	6 (2.6%)	0.050	225 (97.4%)	0.005	0.006
lambda-cyhalothrin	0.003*	0.01	2 (0.9%)	0.017	229 (99.1%)	0.005	0.005
mancozeb	0.023*	0.01	3 (1.3%)	0.114	228 (98.7%)	0.005	0.006
metalaxyl and metalaxyl-M	0.080*	0.01	6 (2.6%)	0.015	225 (97.4%)	0.005	0.005
permethrin	0.050**	0.01	1 (0.4%)	0.078	230 (99.6%)	0.005	0.005

(*): European Commission (EU Pesticides Database) (**): Joint FAO/WHO Meeting on Pesticide Residues (2002).

Table A4. Estimation of dietary exposure for the entire sample (HELLANS 2024-2025) and two latent subgroups (HELLANS 2024-2025 - LPA1 and LPA2)

Pesticide active substance	HELLANS 2024-2025	HELLANS 2024-2025 - LPA1		HELLANS 2024-2025 - LPA2			
		99th mean potato consumption n	99th percentile potato consumption n	99th mean potato consumption n	99th percentile potato consumption n		
imidacloprid	mg/kg bw per day	0.007	0.041	0.004	0.012	0.014	0.058
	% of ADI	0.01%	0.07%	0.01%	0.02%	0.02%	0.10%
fosthiazate	mg/kg bw per day	0.007	0.041	0.004	0.012	0.014	0.058
	% of ADI	0.18%	1.02%	0.11%	0.29%	0.34%	1.45%

fluopyram	mg/kg						
	bw per day	0.006	0.034	0.004	0.010	0.011	0.048
	% of ADI	0.01%	0.03%	0.00%	0.01%	0.01%	0.04%
lambda cyhalothrin	mg/kg						
	bw per day	0.006	0.034	0.004	0.010	0.011	0.048
	% of ADI	0.24%	1.36%	0.15%	0.38%	0.46%	1.94%
mancozeb	mg/kg						
	bw per day	0.007	0.041	0.004	0.012	0.014	0.058
	% of ADI	0.03%	0.18%	0.02%	0.05%	0.06%	0.25%
metalaxyl & metalaxyl-M	mg/kg						
	bw per day	0.006	0.034	0.004	0.010	0.011	0.048
	% of ADI	0.01%	0.04%	0.00%	0.01%	0.01%	0.06%
fenamiphos	mg/kg						
	bw per day	0.007	0.041	0.004	0.012	0.014	0.058
	% of ADI	0.91%	5.08%	0.56%	1.44%	1.72%	7.27%
propamocarb	mg/kg						
	bw per day	0.006	0.034	0.004	0.010	0.011	0.048
	% of ADI	0.00%	0.01%	0.00%	0.00%	0.00%	0.02%
flutolanil	mg/kg						
	bw per day	0.006	0.034	0.004	0.010	0.011	0.048
	% of ADI	0.01%	0.04%	0.00%	0.01%	0.01%	0.05%
dimethomorph	mg/kg						
	bw per day	0.006	0.034	0.004	0.010	0.011	0.048
	% of ADI	0.01%	0.07%	0.01%	0.02%	0.02%	0.10%
permethrin	mg/kg						
	bw per day	0.006	0.034	0.004	0.010	0.011	0.048
	% of ADI	0.01%	0.07%	0.01%	0.02%	0.02%	0.10%
Hazard Index ¹		0.014	0.080	0.009	0.023	0.027	0.114

⁽¹⁾: Hazard Index (HI) calculated as the cumulative sum of the ratios of estimated daily intake to the corresponding acceptable daily intake (ADI) for each active substance assessed: $HI = \sum_i (Intake_i / ADI_i)$, where Intake_i is expressed in g/kg bw/day. HI < 1 suggests low risk based on ADI.

References

1. Camire, M.E.; Kubow, S.; Donnelly, D.J. Potatoes and Human Health. *Critical Reviews in Food Science and Nutrition* **2009**, *49*, 823–840, doi:10.1080/10408390903041996.
2. Burgos, G.; Zum Felde, T.; Andre, C.; Kubow, S. The Potato and Its Contribution to the Human Diet and Health. In *The Potato Crop*; Campos, H., Ortiz, O., Eds.; Springer International Publishing: Cham, 2020; pp. 37–74 ISBN 978-3-030-28682-8.
3. FAO. *New Light on a Hidden Treasure: International Year of the Potato 2008; an End-of-Year Review*; FAO, Ed.; Food and Agriculture Organization of the United Nations: Rome, 2009; ISBN 978-92-5-106142-8.
4. Devaux, A.; Goffart, J.-P.; Kromann, P.; Andrade-Piedra, J.; Polar, V.; Hareau, G. The Potato of the Future: Opportunities and Challenges in Sustainable Agri-Food Systems. *Potato Res.* **2021**, *64*, 681–720, doi:10.1007/s11540-021-09501-4.
5. Devaux, A.; Goffart, J.-P.; Petsakos, A.; Kromann, P.; Gatto, M.; Okello, J.; Suarez, V.; Hareau, G. Global Food Security, Contributions from Sustainable Potato Agri-Food Systems. In *The Potato Crop*; Campos, H., Ortiz, O., Eds.; Springer International Publishing: Cham, 2020; pp. 3–35 ISBN 978-3-030-28682-8.
6. Zaheer, K.; Akhtar, M.H. Potato Production, Usage, and Nutrition—A Review. *Critical Reviews in Food Science and Nutrition* **2016**, *56*, 711–721, doi:10.1080/10408398.2012.724479.
7. Wandel, M.; Fagerli, R.; Kjærnes, U. Changes in Potato Consumption in Different Stages of Life in Norway. *Appetite* **2001**, *36*, 211–223, doi:10.1006/appe.2001.0396.
8. Fernqvist, F.; Spendrup, S.; Ekelund, L. Changing Consumer Intake of Potato, a Focus Group Study. *British Food Journal* **2015**, *117*, 210–221, doi:10.1108/BFJ-05-2013-0112.
9. Wood, K.; Carragher, J.; Davis, R. Australian Consumers' Insights into Potatoes - Nutritional Knowledge, Perceptions and Beliefs. *Appetite* **2017**, *114*, 169–174, doi:10.1016/j.appet.2017.03.038.
10. Gustavsen, G.W. Sustainability and Potato Consumption. *Potato Res.* **2021**, *64*, 571–586, doi:10.1007/s11540-021-09493-1.
11. Paschalidis, Ch.D.; Petropoulos, D.P.; Paschalidis, D.C.; Sotiropoulos, S.S.; Chamurliov, G.O.; Papakonstantinou, L.D. The Importance of Agricultural Land Used in the Production of Agricultural Products in Greece. *Journal of Statistical and Econometric Methods* **2021**, 1–14, doi:10.47260/jsem/1031.
12. Hellenic Ministry of Rural Development and Food. Statistical Data on Areas and Production of Plant Products. Available online: <https://www.minagric.gr/statistikos-tekmirosi/statistikos-diadikasies-dedomena/statistika-stoixeia-ektaseon-kai-paragogis-fytikon-proionton>. Accessed on 04 Sep. 2025.
13. Liu, B.; Gu, W.; Yang, Y.; Lu, B.; Wang, F.; Zhang, B.; Bi, J. Promoting Potato as Staple Food Can Reduce the Carbon–Land–Water Impacts of Crops in China. *Nat Food* **2021**, *2*, 570–577, doi:10.1038/s43016-021-00337-2.
14. Gao, Y.; Alyokhin, A.; Prager, S.M.; Reitz, S.; Huseeth, A. Complexities in the Implementation and Maintenance of Integrated Pest Management in Potato. *Annual Review of Entomology* **2025**, *70*, 45–63, doi:10.1146/annurev-ento-120523-023156.
15. Ziogas, B.N.; Markoglou, A.N.; Theodosiou, D.I.; Anagnostou, A.; Boutopoulou, S. A High Multi-Drug Resistance to Chemically Unrelated Oomycete Fungicides in *Phytophthora Infestans*. *Eur J Plant Pathol* **2006**, *115*, 283–292, doi:10.1007/s10658-006-9007-6.
16. Cooke, L.R.; Schepers, H.T.A.M.; Hermansen, A.; Bain, R.A.; Bradshaw, N.J.; Ritchie, F.; Shaw, D.S.; Evenhuis, A.; Kessel, G.J.T.; Wander, J.G.N.; et al. Epidemiology and Integrated Control of Potato Late Blight in Europe. *Potato Res.* **2011**, *54*, 183–222, doi:10.1007/s11540-011-9187-0.
17. Kroschel, J.; Schaub, B. Biology and Ecology of Potato Tuber Moths as Major Pests of Potato. In *Insect Pests of Potato*; Elsevier, 2013; pp. 165–192 ISBN 978-0-12-386895-4.
18. Kocourek, F.; Dolezal, P.; Hausvater, E.; Horska, T.; Sopko, B.; Sedlak, P.; Sedlakova, V.; Stara, J. Six-Year Monitoring of Pesticide Resistance in the Colorado Potato Beetle (*Leptinotarsa Decemlineata* Say) during a Neonicotinoid Restriction Period. *PLoS ONE* **2024**, *19*, e0303238, doi:10.1371/journal.pone.0303238.
19. European Food Safety Authority (EFSA); Brancato, A.; Brocca, D.; De Lentdecker, C.; Erdos, Z.; Ferreira, L.; Greco, L.; Jarrah, S.; Kardassi, D.; Leuschner, R.; et al. Review of the Existing Maximum Residue Levels for Chlorpyrifos According to Article 12 of Regulation (EC) No 396/2005. *EFSA* **2017**, *15*, doi:10.2903/j.efsa.2017.4733.

20. European Food Safety Authority (EFSA) Statement on the Available Outcomes of the Human Health Assessment in the Context of the Pesticides Peer Review of the Active Substance Chlorpyrifos. *EFSA* **2019**, *17*, doi:10.2903/j.efsa.2019.5809.
21. Simoglou, K.B.; Roditakis, E. Consumers' Benefit—Risk Perception on Pesticides and Food Safety—A Survey in Greece. *Agriculture* **2022**, *12*, 192, doi:10.3390/agriculture12020192.
22. Koch, S.; Epp, A.; Lohmann, M.; Böhl, G.-F. Pesticide Residues in Food: Attitudes, Beliefs, and Misconceptions among Conventional and Organic Consumers. *Journal of Food Protection* **2017**, *80*, 2083–2089, doi:10.4315/0362-028X.JFP-17-104.
23. Nitzko, S.; Bahrs, E.; Spiller, A. Pesticide Residues in Food and Drinking Water from the Consumer's Perspective: The Relevance of Maximum Residue Levels and Product-Specific Differences. *Sustainable Production and Consumption* **2022**, *30*, 787–798, doi:10.1016/j.spc.2022.01.016.
24. Simoglou, K.B.; Skarpa, P.El.; Roditakis, E. Pesticides and Eroding Food Citizenship: Understanding Individuals' Perspectives on the Greek Food System. *Agrochemicals* **2025**, *4*, 3, doi:10.3390/agrochemicals4010003.
25. Sandoval-Insausti, H.; Chiu, Y.-H.; Lee, D.H.; Wang, S.; Hart, J.E.; Mínguez-Alarcón, L.; Laden, F.; Ardisson Korat, A.V.; Birmann, B.; Heather Eliassen, A.; et al. Intake of Fruits and Vegetables by Pesticide Residue Status in Relation to Cancer Risk. *Environment International* **2021**, *156*, 106744, doi:10.1016/j.envint.2021.106744.
26. Baudry, J.; Rebouillat, P.; Samieri, C.; Berlivet, J.; Kesse-Guyot, E. Dietary Pesticide Exposure and Non-Communicable Diseases and Mortality: A Systematic Review of Prospective Studies among Adults. *Environ Health* **2023**, *22*, 76, doi:10.1186/s12940-023-01020-8.
27. Cavalier, H.; Trasande, L.; Porta, M. Exposures to Pesticides and Risk of Cancer: Evaluation of Recent Epidemiological Evidence in Humans and Paths Forward. *Intl Journal of Cancer* **2023**, *152*, 879–912, doi:10.1002/ijc.34300.
28. Rebouillat, P.; Vidal, R.; Cravedi, J.-P.; Taupier-Letage, B.; Debrauwer, L.; Gamet-Payrastrre, L.; Touvier, M.; Deschasaux-Tanguy, M.; Latino-Martel, P.; Hercberg, S.; et al. Prospective Association between Dietary Pesticide Exposure Profiles and Postmenopausal Breast-Cancer Risk in the NutriNet-Santé Cohort. *International Journal of Epidemiology* **2021**, *50*, 1184–1198, doi:10.1093/ije/dyab015.
29. Rebouillat, P.; Vidal, R.; Cravedi, J.-P.; Taupier-Letage, B.; Debrauwer, L.; Gamet-Payrastrre, L.; Guillou, H.; Touvier, M.; Fezeu, L.K.; Hercberg, S.; et al. Prospective Association between Dietary Pesticide Exposure Profiles and Type 2 Diabetes Risk in the NutriNet-Santé Cohort. *Environ Health* **2022**, *21*, 57, doi:10.1186/s12940-022-00862-y.
30. Reiss, R.; Johnston, J.; Tucker, K.; DeSesso, J.M.; Keen, C.L. Estimation of Cancer Risks and Benefits Associated with a Potential Increased Consumption of Fruits and Vegetables. *Food and Chemical Toxicology* **2012**, *50*, 4421–4427, doi:10.1016/j.fct.2012.08.055.
31. Valcke, M.; Bourgault, M.-H.; Rochette, L.; Normandin, L.; Samuel, O.; Belleville, D.; Blanchet, C.; Phaneuf, D. Human Health Risk Assessment on the Consumption of Fruits and Vegetables Containing Residual Pesticides: A Cancer and Non-Cancer Risk/Benefit Perspective. *Environment International* **2017**, *108*, 63–74, doi:10.1016/j.envint.2017.07.023.
32. Chiu, Y.-H.; Sandoval-Insausti, H.; Ley, S.H.; Bhupathiraju, S.N.; Hauser, R.; Rimm, E.B.; Manson, J.E.; Sun, Q.; Chavarro, J.E. Association between Intake of Fruits and Vegetables by Pesticide Residue Status and Coronary Heart Disease Risk. *Environment International* **2019**, *132*, 105113, doi:10.1016/j.envint.2019.105113.
33. Chiu, Y.H.; Afeiche, M.C.; Gaskins, A.J.; Williams, P.L.; Petrozza, J.C.; Tanrikut, C.; Hauser, R.; Chavarro, J.E. Fruit and Vegetable Intake and Their Pesticide Residues in Relation to Semen Quality among Men from a Fertility Clinic. *Human Reproduction* **2015**, *30*, 1342–1351, doi:10.1093/humrep/dev064.
34. Chiu, Y.-H.; Williams, P.L.; Gillman, M.W.; Gaskins, A.J.; Mínguez-Alarcón, L.; Souter, I.; Toth, T.L.; Ford, J.B.; Hauser, R.; Chavarro, J.E.; et al. Association Between Pesticide Residue Intake From Consumption of Fruits and Vegetables and Pregnancy Outcomes Among Women Undergoing Infertility Treatment With Assisted Reproductive Technology. *JAMA Intern Med* **2018**, *178*, 17, doi:10.1001/jamainternmed.2017.5038.
35. Sandoval-Insausti, H.; Chiu, Y.-H.; Wang, Y.-X.; Hart, J.E.; Bhupathiraju, S.N.; Mínguez-Alarcón, L.; Ding, M.; Willett, W.C.; Laden, F.; Chavarro, J.E. Intake of Fruits and Vegetables According to Pesticide Residue

- Status in Relation to All-Cause and Disease-Specific Mortality: Results from Three Prospective Cohort Studies. *Environment International* **2022**, *159*, 107024, doi:10.1016/j.envint.2021.107024.
36. European Food Safety Authority (EFSA); Craig, P.S.; Dujardin, B.; Hart, A.; Hernández-Jerez, A.F.; Hougaard Bennekou, S.; Kneuer, C.; Ossendorp, B.; Pedersen, R.; Wolterink, G.; et al. Cumulative Dietary Risk Characterisation of Pesticides That Have Acute Effects on the Nervous System. *EFSA* **2020**, *18*, doi:10.2903/j.efsa.2020.6087.
 37. European Food Safety Authority (EFSA); Craig, P.S.; Dujardin, B.; Hart, A.; Hernandez-Jerez, A.F.; Hougaard Bennekou, S.; Kneuer, C.; Ossendorp, B.; Pedersen, R.; Wolterink, G.; et al. Cumulative Dietary Risk Characterisation of Pesticides That Have Chronic Effects on the Thyroid. *EFSA* **2020**, *18*, doi:10.2903/j.efsa.2020.6088.
 38. European Food Safety Authority (EFSA); Dujardin, B. Comparison of Cumulative Dietary Exposure to Pesticide Residues for the Reference Periods 2014–2016 and 2016–2018. *EFSA* **2021**, *19*, doi:10.2903/j.efsa.2021.6394.
 39. European Food Safety Authority (EFSA); Anastassiadou, M.; Choi, J.; Coja, T.; Dujardin, B.; Hart, A.; Hernandez-Jerez, A.F.; Jarrah, S.; Lostia, A.; Machera, K.; et al. Cumulative Dietary Risk Assessment of Chronic Acetylcholinesterase Inhibition by Residues of Pesticides. *EFSA* **2021**, *19*, doi:10.2903/j.efsa.2021.6392.
 40. European Food Safety Authority (EFSA); Anagnostopoulos, C.; Anastassiadou, M.; Castoldi, A.F.; Cavellier, A.; Coja, T.; Crivellente, F.; Dujardin, B.; Hart, A.; Hooghe, W.; et al. Retrospective Cumulative Dietary Risk Assessment of Craniofacial Alterations by Residues of Pesticides. *EFSA* **2022**, *20*, doi:10.2903/j.efsa.2022.7550.
 41. Ministry of Rural Development and Food, 2025. Greek results from the monitoring of pesticide residues in food (version 9) [Data set]. *Zenodo* **2025**. <https://doi.org/10.5281/ZENODO.15398997>
 42. Trichopoulou, A.; Orfanos, P.; Valanou, E.; Martimianaki, G.; Peppas, E.; Androulidaki, A.; Anifantis, E.; Katsoulis, M.; Kritikou, M.; Pantzarlis, M.; et al. The EFSA-funded Collection of Dietary and Related Data in the General Population Aged 10-74 Years in Greece. *EFSA* **2018**, *15*, doi:10.2903/sp.efsa.2018.EN-1499.
 43. USDA. Food and Nutrient Database for Dietary Studies Documentation and Databases. Available online: <https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/fndds-download-databases/>. Accessed on 15 April 2024.
 44. Thompson, F.E.; Subar, A.F. Dietary Assessment Methodology. In *Nutrition in the Prevention and Treatment of Disease*; Elsevier, 2017; pp. 5–48 ISBN 978-0-12-802928-2.
 45. Vilone, G.; Comiskey, D.; Heraud, F.; O'Mahony, C. Statistical Method to Assess Usual Dietary Intakes in the European Population. *Food Additives & Contaminants: Part A* **2014**, *31*, 1639–1651, doi:10.1080/19440049.2014.955886.
 46. European Food Safety Authority (EFSA); Brancato, A.; Brocca, D.; Ferreira, L.; Greco, L.; Jarrah, S.; Leuschner, R.; Medina, P.; Miron, I.; Nougadere, A.; et al. Use of EFSA Pesticide Residue Intake Model (EFSA PRIMo Revision 3). *EFSA* **2018**, *16*, doi:10.2903/j.efsa.2018.5147.
 47. European Commission, 2025. EU Pesticide Database. Accessed on 14 Aug. 2025. Available at: https://food.ec.europa.eu/plants/pesticides/eu-pesticides-database_en
 48. Ritzoulis, C. Moussaka as an introduction to food chemistry, pp. 45-51. In: *The Kitchen as Laboratory: Reflections on the Science of Food and Cooking*; Vega, C., Ubbink, J., Linden, E. van der, Steingarten, J., Eds.; Arts and traditions of the table: perspectives on culinary history; Columbia University Press: New York Chichester, 2013; ISBN 978-0-231-15345-4.
 49. Quijano, L.; Yusà, V.; Font, G.; Pardo, O. Chronic Cumulative Risk Assessment of the Exposure to Organophosphorus, Carbamate and Pyrethroid and Pyrethrin Pesticides through Fruit and Vegetables Consumption in the Region of Valencia (Spain). *Food and Chemical Toxicology* **2016**, *89*, 39–46, doi:10.1016/j.fct.2016.01.004.
 50. Hair, J.F.; Black, W.C.; Babin, B.J.; Anderson, R.E. *Multivariate Data Analysis*; Eighth edition.; Cengage: Andover, Hampshire, 2019; ISBN 978-1-4737-5654-0.

51. Collins, L.M.; Lanza, S.T. *Latent Class and Latent Transition Analysis: With Applications in the Social Behavioral, and Health Sciences*; Wiley series in probability and statistics; Wiley: Hoboken, N.J, 2010; ISBN 978-0-470-22839-5.
52. Moore, E.W.G.; Quartiroli, A. Representing Subpopulations with Latent Profile Analysis: A Non-Technical Introduction Using Exercisers' Goal Orientation Adoption Profiles. *J Behav Med* **2025**, doi:10.1007/s10865-025-00596-5.
53. The jamovi project. jamovi (Version 2.7) [Computer Software]. Available at: <https://www.jamovi.org>
54. Rosenberg, J.; Beymer, P.; Anderson, D.; Van Lissa, C. j.; Schmidt, J. tidyLPA: An R Package to Easily Carry Out Latent Profile Analysis (LPA) Using Open-Source or Commercial Software. *JOSS* **2018**, *3*, 978, doi:10.21105/joss.00978.
55. Endo, T.; Watanabe, T.; Yamamoto, A. Confidence Interval Estimation by Bootstrap Method for Uncertainty Quantification Using Random Sampling Method. *Journal of Nuclear Science and Technology* **2015**, *52*, 993–999, doi:10.1080/00223131.2015.1034216.
56. ELSTAT (Hellenic Statistics Authority). Results of 2021 population and housing census. Available online: <https://www.statistics.gr/en/2021-census-res-pop-results>. Accessed on 28-08-2025.
57. Schenke, K.; Ruzek, E.; Lam, A.C.; Karabenick, S.A.; Eccles, J.S. Heterogeneity of Student Perceptions of the Classroom Climate: A Latent Profile Approach. *Learning Environ Res* **2017**, *20*, 289–306, doi:10.1007/s10984-017-9235-z.
58. Vermunt, J.K., Magidson, J. Latent Class Cluster Analysis, pp. 89-106. In: *Applied Latent Class Analysis*; Hagenaars, J.A., McCutcheon, A.L., Eds.; 1st ed.; Cambridge University Press, 2002; ISBN 978-0-521-59451-6.
59. Gad Alla, S.A.; Loutfy, N.M.; Shendy, A.H.; Ahmed, M.T. Hazard Index, a Tool for a Long Term Risk Assessment of Pesticide Residues in Some Commodities, a Pilot Study. *Regulatory Toxicology and Pharmacology* **2015**, *73*, 985–991, doi:10.1016/j.yrtph.2015.09.016.
60. Slovic, P.; Malmfors, T.; Krewski, D.; Mertz, C.K.; Neil, N.; Bartlett, S. Intuitive Toxicology. II. Expert and Lay Judgments of Chemical Risks in Canada. *Risk Analysis* **1995**, *15*, 661–675, doi:10.1111/j.1539-6924.1995.tb01338.x.
61. European Food Safety Authority. *Food Safety in the EU*; Publications Office: LU, 2019; EFSA, <https://data.europa.eu/doi/10.2805/661752>.
62. Jaskiewicz, K.; Taylor, O.; Senior, B.; Maestre, M. Communication of Food-related Health Risks and Benefits – a Systematic Review (2018-2022). *EFSA* **2023**, *20*, doi:10.2903/sp.efsa.2023.EN-8203.
63. Baba, F.V.; Esfandiari, Z. Theoretical and Practical Aspects of Risk Communication in Food Safety: A Review Study. *Heliyon* **2023**, *9*, e18141, doi:10.1016/j.heliyon.2023.e18141.
64. European Food Safety Authority (EFSA); Carrasco Cabrera, L.; Di Piazza, G.; Dujardin, B.; Marchese, E.; Medina Pastor, P. The 2023 European Union Report on Pesticide Residues in Food. *EFSA* **2025**, *23*, doi:10.2903/j.efsa.2025.9398.
65. Jensen, B.H.; Petersen, A.; Nielsen, E.; Christensen, T.; Poulsen, M.E.; Andersen, J.H. Cumulative Dietary Exposure of the Population of Denmark to Pesticides. *Food and Chemical Toxicology* **2015**, *83*, 300–307, doi:10.1016/j.fct.2015.07.002.
66. Witczak, A.; Pohoryło, A.; Abdel-Gawad, H.; Cybulski, J. Residues of Some Organophosphorus Pesticides on and in Fruits and Vegetables Available in Poland, an Assessment Based on the European Union Regulations and Health Assessment for Human Populations. *Phosphorus, Sulfur, and Silicon and the Related Elements* **2018**, *193*, 711–720, doi:10.1080/10426507.2018.1492921.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.