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Amélie Kurtz, Rallou Thomopoulos

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Safety vs. Sustainability Concerns of Infant Food Users: French Results and European Perspectives

Amélie Kurtz and Rallou Thomopoulos *

INRAE, Institut Agro, IATE, University of Montpellier, F-34060 Montpellier, France; amelie.kurtz@agroparistech.fr
* Correspondence: rallou.thomopoulos@inrae.fr

Abstract: *Context.* In line with Sustainable Development Goals 3 "Good health and well-being" and 12 "Responsible Consumption and Production", this paper is concerned with the fragile population of the less-than-3-years-old children. More specifically, it investigates how infant food safety is perceived at the household level and at the level of childhood and health professionals directly in contact with them. *Objective.* The paper aims to analyze consumer priorities and perceptions of hazards in infant foods qualitatively and quantitatively. *Methodology.* To do so, a survey was carried out in France on 1750 people representative of the general population. A hybrid method is proposed to analyze the results of the survey, mixing artificial intelligence and statistics. *Main insights.* Within the declared priorities when choosing infant food, health comes first, with a top ranking for the absence of harmful substances, followed closely by nutritional balance—far ahead of environment, ease of use and price. The results show that the rankings of the hazards that cause the most worry are globally homogeneous throughout the populations (families, professionals, etc.) and higher for chemical contaminants from agricultural practices and packaging. For health professionals, concerns are higher than in the general population for all categories of contaminants, and specific concerns such as risk related to environmental and unknown contaminants are much more prevalent. The perception of risk varies with the food considered. For infant formula in particular, users seem puzzled by somehow contradictory messages. *Perspectives.* The study is intended to be generalized to Europe.

Keywords: sustainable consumption; survey; baby food; argument; data science

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1. Introduction

As a public health issue worldwide, food safety is a major concern for society and a responsibility for public authorities and food supply chain actors [1,2]. Traditional food systems, as opposed to industrialized ones, are frequently blamed for food safety issues. For low-income countries, food safety is pointed out as a serious concern, mostly related to microbiological contamination (bacteria and viruses causing illnesses such as diarrhea, parasites, etc.) and mainly affecting children under the age of five [3].

However, the emergence of industrialized food systems in developing, low-income countries is not exempt from new risks [4]. The use of pesticides, veterinary drugs, food additives, and industrial processes, while contributing to control biological hazards, brings chemical hazards from farm to fork. Moreover, the elongation of food chains increases the number of middlemen, which can lead to increased fraud [5]. Impacts on public health may only be visible and measured in the long term. Longstanding medical literature establishes that such contaminants can contribute to health problems, including cancers, lung disease or reproductive, endocrinal and immune system disorders. In addition, it highlights that children are more vulnerable to these risks [6,7].

In addition to effects on human health, wide-ranging implications for the environment are notable. According to [8], the use of pesticides at the global level nearly doubled between 1990 and 2018, with consequences on soil, water and air pollution, on pollinating insects, on human health, on resistance of development within crop pests, while decreased uses appear sparse, limited and localized [9]. This phenomenon does not spare industrialized countries, where increased quantities of active substances in the agrochemicals sold were observed in the latest years, while the utilized agricultural area was lightly decreasing [10].

Contaminated food also contributes to significant food losses, as in the case of mycotoxins, hence generating food insecurity, and causes hurdles to agricultural commodity trade. The suspicion of unsafe food itself can, as in large-scale food safety crises, have serious political and economic consequences [4]. Furthermore, industrial food systems produce significant amounts of food packaging, which contributes to food safety, but also to trash and pollution, which has a negative influence on public health [11].

Health authorities have carried out large-scale studies to identify the main hazards in food intended for the vulnerable public of young children under the age of three [12,13]. The current European legislative frameworks that governs the safety of infant food set strict requirements for their composition and labeling [14]. Nevertheless, improving food safety and sustainability necessitates the participation and cooperation of a wide range of stakeholders, including the food industry but also the household level. In a recent study [15], young generations showed little concern about food safety and limited trust in food control agencies. They hold food producers and food processing companies as mainly responsible for food safety, while retailers and consumers were perceived as the least responsible ones. This result highlights public awareness is needed, and food chain stakeholders need to be trained and organized to contribute to the collective effort required to improve food safety, such as the adoption of good practice guidelines from farm to fork. This is one of the objectives of the ongoing research program "Safe food for infants" [16,17], which relies on the collaboration of stakeholders for this purpose.

In the present paper, the focus is on perceptions of infant food safety for different food products at the level of infant food users, including primarily parents, relatives, but also professionals of early childhood, of child healthcare and general practitioners. The general question addressed by the paper can be expressed as follows: How do infant food users set the balance between the various sustainability concerns?—safety versus environment in particular. The more specific questions are:

- Do the answers expressed by infant food users provide arguments for focusing (or not) on the prevention of specific safety hazards from the viewpoint of infant food users?
- For what food products?
- Are there differences between societal target groups?
- Are these concerns connected with other sustainability concerns, and how?

A combination of methods is proposed to address these questions, relying on Artificial Intelligence (AI) and statistics.

The paper is organized as follows. In Section 2, we describe the materials and methods used, which are composed of three subparts: the survey designed (Section 2.1), the AI analyses performed (Section 2.2), and the statistical analyses performed (Section 2.3). Section 3 presents the corresponding results, with due regard to successively addressing the general and specific questions expressed above. In Section 4, we discuss the interpretation of the results obtained.

2. Materials and Methods

2.1. Survey Design

In order to obtain insights on infant food users' perceptions of food safety in relation to wider concerns, several complementary strategies are considered, in particular (i) survey analysis [18,19], which is the approach presented in this paper and (ii) web mining [20,21], which is ongoing research. We conducted an online survey among a panel of 1,750 French citizens. The survey is composed of 18 groups of questions and 49 individual questions, all closed-ended, belonging to the following categories:

- Status of the respondent: does she/he take care of children under the age of 3, with what status (parent, professional, etc.). The former question serves as a filter allowing one to identify actual users of infant foods.
- Use of ready-to-use infant foods, versus other types of foods: ready-to-use for the general public (not specifically intended for young children) or homemade. The regular use of organic food is also specified.
- Priorities when buying infant food (not restricted to safety concerns). The question asked is "What are your priorities when choosing an infant meal?", with 9 items each evaluated on from "priority" to"non-essential": food balance, price, ease of use, allergen-free, contaminant-free, educating the child's taste, environment-friendly, adapted to the child's capabilities, and limiting waste.
- General opinions about ready-to-use infant foods (not restricted to safety concerns).
- Concerns about the microbiological safety of ready-to-use infant foods:
  – For which contaminants among the following items: bacteria that may cause digestive problems, bacteria that may cause severe poisoning, viruses, parasites, and unknown pathogens; to what extent, i.e., regular, occasional, or rare/no concern.
  – In which foods, among four types of food considered: sterilized baby food jars with vegetable and fish, powdered infant formula, pasteurized fruit compote, and infant cereals; to what extent on a Likert scale [22].
- Concerns about the chemical safety of ready-to-use infant foods:
  – For which contaminants among the following items: contaminants from the environment (heavy metals, dioxins, etc.), from agricultural practices (pesticides, mycotoxins, etc.), from industrial processes (substances resulting from cooking, etc.), from packaging (plastics, etc.), fraudulently introduced contaminants, unknown harmful substances; to what extent, i.e., regular, occasional, or rare/no concern.
  – In which foods, among the four types mentioned above; to what extent on a Likert scale.
- Socio-demographic profile.

The survey was designed using the Limesurvey tool [23]. It was then launched in December 2020 by the Crowdpanel polling company in order to ensure a representative sample of the French population. Answers to the survey, in CSV format, contain 51 columns corresponding to the 49 individual questions complemented with answer ID and duration, also referred to as "variables" in the rest of the paper when dealing with data analysis.

2.2. *AI-Based Data Analysis*

The objective of this AI approach is to compute, from the raw data, the so-called "collective attitudes", which are then used as the major indicator in this study, then further analyzed and visualized using classic statistics, as presented in Section 2.3. The AI method is composed of two steps: (i) Extracting pro and con arguments from the data (Section 2.2.2), and (ii) computing the collective attitudes from these arguments (Section 2.2.3). We start with some background on argumentation models in Section 2.2.1.

2.2.1. Argumentation Models

The first type of method used to analyze the results comes from the area of Artificial Intelligence (AI) and more precisely from the field of argumentation [24]. Argumentation is a reasoning model based on the construction and evaluation of interacting arguments. It has been formalized both in philosophy [25,26] and in computer science [24] and adapted to various uses such as dialogue modeling, negotiation [27,28] and decision making [29,30]. Historically, the prototypical application field of argumentation in computer science was the legal domain [31]. More recently, several works proved its relevance in a larger context, in social-related concerns [32], medicine [33,34], bioproducts [35], and also food systems both upstream [36] and downstream [37,38].

Various formal approaches of argumentation have been proposed in the literature. Two main families are generally distinguished:

1. Abstract models, introduced by Dung's seminal work [39]. In [39], an argumentation system consists of a set of arguments and a binary relation on that set, expressing conflicts among arguments. An argument is an abstract entity whose role is solely determined by its relations to other arguments. No special attention is paid to the internal structure of the arguments. A difficulty in using this approach in real-world case studies is how to practically define and represent an argument in order to reflect the statements of a debate. In practice, even when Dung's formalism is used for an overview of the debate (e.g., [35,40,41] in the food sector), a more detailed representation of the internal content of arguments is additionally chosen, which falls into the scope of the second family of approaches.
2. Logical models [42], in which an argument is represented as a set of statements composed of a conclusion and at least one premise, linked by an inference relation. Hence, an argument explicitly gives a reason—the premise, also referred to as "support" or "hypothesis"—for believing a claim or doing an action—the conclusion, also referred to as "consequence" or "alternative". The authors of [37,43] provide examples of food-related applications using such approaches. Furthermore, bipolar approaches, as proposed in [44], allowed distinguishing between "pro" arguments, in favor of a claim, and "con" arguments, against the claim, thus factoring in undesirable consequences. Bipolarity refers to the human reasoning that combines information on pros with information on cons to make decisions, choices, or judgments.

An additional, more recent approach, relates to the second one since it proposes a structured representation of arguments, but adopts a database—rather than a logical—modeling of arguments, allowing for a very extensive description of arguments with the purpose of performing selective argument analysis [41] based on the criteria, stakeholders, expertise, or source viability considered, and integrating bipolarity. Initiated in [40], it was further used in later works [38,45] and implemented in a software tool outlined in [46]. This tool [47] is used for data analysis in the present paper.

2.2.2. Defining Arguments

The central question of the present study is to identify information that contributes to justify, from infant food users' viewpoint, the decision to focus (or not) future food safety research and studies on some families of contaminants in particular, whether they are biological or chemical.

To this end, answers to each question of the group "Concerns about the microbiological safety of ready-to-use infant foods" and "Concerns about the chemical safety of ready-to-use infant foods" were processed through an interpretation algorithm we developed in the Java programming language. The principle of this program is the following:

- For each question, defined for a specific contaminant *c* and measuring to what extent the respondent feels concerned, if the answer is "regularly", a new "pro" argument is generated as a new input of a CSV file in the format of [46,47]. This argument expresses regular consumer concern as a reason for focusing on contaminant *c*.
- If the answer is "rarely or never", a new "con" argument is generated. This argument expresses consumer absence of concern as a reason for not focusing on contaminant *c*.
- If the answer is "occasionally", no argument is generated. Indeed, as noted by [22], middle-valued answers cannot be interpreted as clear-cut answers.
- The category of infant food user—parent, family or relatives, early childhood professional, healthcare professional specialized in early childhood, or general health professional—is obtained from the answers given by the same respondent to the first questions of the survey ("status of the respondent") and added to the argument description.

The same method was used to define arguments in favor, or against, focusing on a type of food, from infant food users' viewpoint.

2.2.3. The Notion of Collective Attitude

Classically in social psychology, the concept of "attitude" refers to an individual measure, defined for each participant individually, through specifically designed questionnaires [48,49]. Several understandings of attitude exist, synonymous or not with the notion of opinion, with no uniform definition so far [50]. In [46,47], a proposal to define a collective attitude is introduced, which we adopt here. This approach, based on the preliminary collection of arguments from a variety of sources and stakeholders on a debated topic, is oriented towards collective assessment. It may be performed at an early stage of the debate, since it is dynamically updated with the arrival of new arguments.

Let us use the following notations:

- $n^+_{c,u}$ denotes the number of "pro" arguments in favor of focusing on a contaminant c for a given category of infant food users u,
- $n_{c,u}$ denotes the total number of arguments ("pro" and "con") on c for the user category u,
- n_u denotes the total number of arguments ("pro" and "con") on all contaminants for the user category u,
- n denotes the total number of arguments, for all contaminants and user categories,
- U is the set of all categories of infant food users considered.

The collective attitude for focusing on c is defined as follows:

$$Collective\_attitude(c) = \frac{1}{n} \sum_{U} n_u \frac{n^+_{c,u} + 1}{n_{c,u} + 2}. \quad (1)$$

It is thus a real number between 0 and 1. The values of 0 and 1 are limits (never reached), respectively, expressing total rejection and total adhesion, while 0.5 corresponds to the status of ignorance—in the absence of arguments—or ambivalence—in the presence of arguments. This attitude value can also be computed for restricted viewpoints, e.g., specific stakeholders (health professionals only, etc.), which will be used in Section 3.5.

2.3. Statistical Data Analysis

In addition to the AI analysis, classic statistics were carried out using the R software [51], with 3 different objectives:

- Check the representativity of the respondents' profiles in regards to the general population.
- Check the significance of the collective attitude differences observed between subpopulations.
- Test the dependencies between variables and the predictibility of variables of interest: "priority of the criterion absence of harmful substances when buying baby food", "concern for contaminants from agriculture" and "concern for contaminants from packaging".

Therefore, analyses were carried out on respondent profiles with pivot tables and statistic tests. To determine the dependencies between variables and to predict binary variables, chi-square tests were performed, eliminating almost empty categories. Pearson residuals were used as indicators for negative and positive dependencies between modalities of variables. Finally, a prediction of variables of interest was performed using the general linear model (GLM) [52], which is commonly used in machine learning and stands as an improvement of linear regression. A deviance test was performed between this model and the null model. Insignificant variables were eliminated with the likelihood test. Predicted answers were then compared with real observations to estimate the quality of prediction.

GLM is thus used here as a post-processing step, following AI analysis. The performance of various machine learning methods has been explored in the literature, including in an applied context [19,53,54]. In [53], the advantages and disadvantages induced by the use of novel machine learning techniques such as tree-boosted models over GLM were carefully analyzed in the context of customers' behavior analysis. The conclusions are fourfold: (i) The results are dependent on the dataset and sample size—which is confirmed by [54]. (ii) Machine learning models offer higher global accuracy when compared to classical GLM models. (iii) The results are very similar for variables that have been found to be most important, especially between GLM and XGBoost approaches, and (iv) regarding the computational resources, fitting a GLM clearly takes a very small fraction of the computational time required by most machine learning models. Consequently, in our context, GLM appears sufficient for post-processing purposes. It was selected for its simplicity and ease of implementation and interpretation.

3. Results

3.1. General Description

A total of 59% of the participants declare they are regularly (28%) or occasionally (31%) involved in the meals of children under 3 years old. In the population of respondents, women represent 52% and men 48%. A total of 39% are parents of young children under 3 years old, 54% are family or relatives. Early childhood professionals (outside the health sector) represent 6.5% of the respondents, general health practitioners represent 4.5% and healthcare professionals specialized in early childhood represent 2% of the respondents.

It is worth noting that 82% of the respondents declare the child's meals have regularly or occasionally included ready-to-use infant foods, but 18% declare they rarely or never have. Furthermore, 54% declare the child's meals have regularly or occasionally included "general public" foods, and only 46% declare they have not. Thus, the use of non-specialized food for the less-than-3 year olds appears widespread.

The representativity of the sample in regard to the general population was verified regarding the repartition of gender, age of mother, family status, number of children per mother, living environment and work situation. Nonetheless, it should be noted that the "family" group—parents excluded—which is largely composed of respondents between 20 and 29 years old or above 49 years old, seems to somehow over-represent the young rather than the grand-parents' group. This may be due to the form of the survey, which was diffused online, possibly introducing some bias in the sample recruited.

3.2. How Do Infant Food Users Set the Balance between the Various Sustainability Concerns?

Figure 1 summarizes the answers to the question: "What are your priorities when choosing an infant meal?"

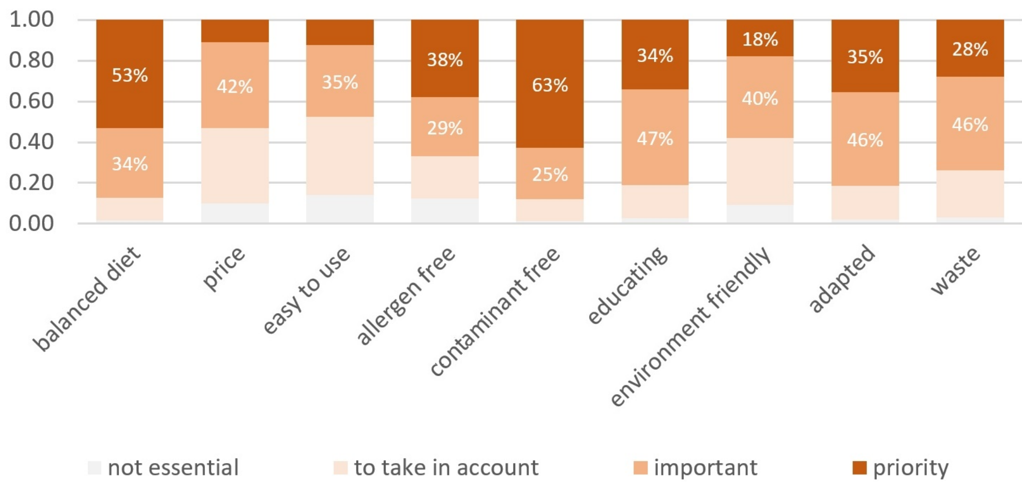


Figure 1. Consumers' priorities when choosing infant food.

Three levels of priority can be distinguished:

- The absence of contaminants comes first, with 63% of consumers considering the absence of harmful substances priority and a further 25% as important. Only 1% estimated the absence of contaminants as non-essential. This safety criterion is quite closely followed by the nutritional criterion, yet with a lower proportion of "priority" evaluations, compensated by a higher proportion of "important" evaluations.
- Next in the ranking of criteria comes the adequacy of food with the child's capabilities and preferences, its value in educating the child's taste, the absence of allergens, and the limitation of waste.
- Finally, environmental protection goes beyond, yet is related, to the "waste" criterion. The price and ease of use criteria come last.

3.3. Which Safety Hazards Should Be Focused On, from the Viewpoint of Infant Food Users?

Figure 2 displays the collective attitudes of infant food users regarding different food safety hazards. Chemical hazards are displayed in red, microbiological hazards in green—from pale to dark depending on the value of the collective attitude.

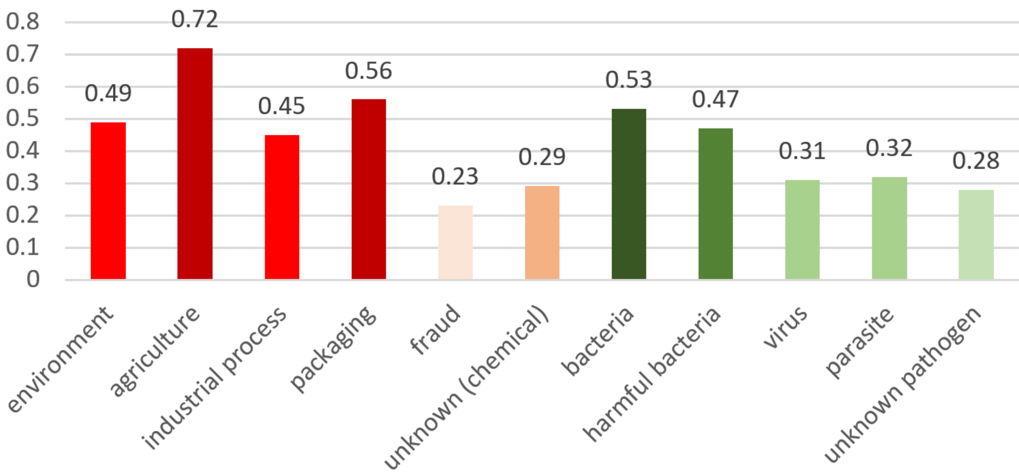


Figure 2. Infant food users' collective attitudes regarding chemical hazards (in red) and microbiological hazards (in green).

Collective attitudes above 0.5 can be interpreted as the expression of a significant and regular concern. Conversely, collective attitudes below 0.5 indicate that the absence of any concern, even occasional, is more strongly claimed than the presence of regular concern.

Alarming signals from infant food users can be noted for three categories of contaminants:

1. The highest collective attitude (0.72) goes for contaminants from agricultural practices, such as pesticides, indicating a high predominance of concerns about this category of hazards.
2. The second highest concern is that of contaminants from packaging, such as plastics, with a collective attitude of 0.56.
3. The third concern is microbiological. It is expressed for bacteria that may cause low to moderate digestive disorders, with a collective attitude of 0.53.

These predominant concerns are followed by more discrete ones: contaminants from the environment, bacteria responsible for severe diseases, and contaminants from industrial processes, are not far beyond.

The other hazards (parasites, viruses, unknown chemicals or pathogens, fraud) are not prevalent in the global population of respondents.

3.4. Which Foods Should Be Focused On, from the Viewpoint of Infant Food Users?

Figure 3 displays the collective attitudes of infant food users regarding the safety of different baby foods.

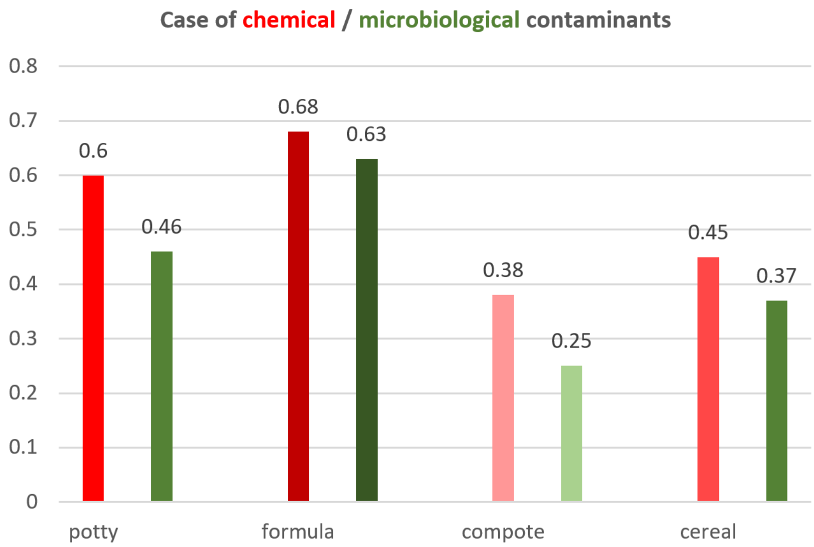


Figure 3. Infant food users' collective attitudes regarding the safety of different types of baby food.

Powdered infant formula, and potties with vegetable and fish, obtain the highest collective attitudes, which expresses a higher degree of concern. Furthermore, for all baby foods, chemical contaminants have higher collective attitudes, i.e., cause higher concern among infant food users. This is in line with the results of Section 3.3.

Infant cereals and fruit compotes have collective attitudes below 0.5, indicating that the absence of concern is predominant over regular concern. Similarly, the safety of potties with vegetable and fish can be interpreted as a concern for infant food users only for chemical contaminants.

3.5. Are There Differences between Societal Target Groups?

Previous works have shown that to best feed their child, families and especially mothers tend to primarily refer to the pediatrician until the child reaches the age of two, then to the general practitioner, the entourage and the experience [55,56]. Therefore, we chose to focus on (a) parents and families and (b) professionals of early childhood and health. Figure 4 shows the collective attitudes towards categories of chemical contaminants for these target groups.

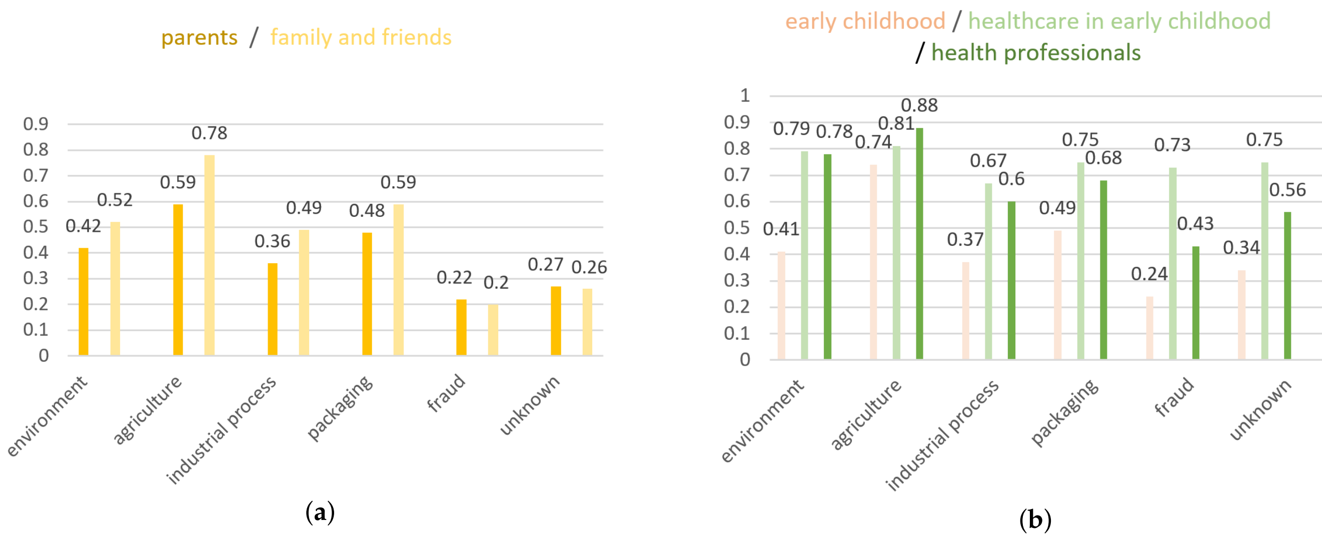
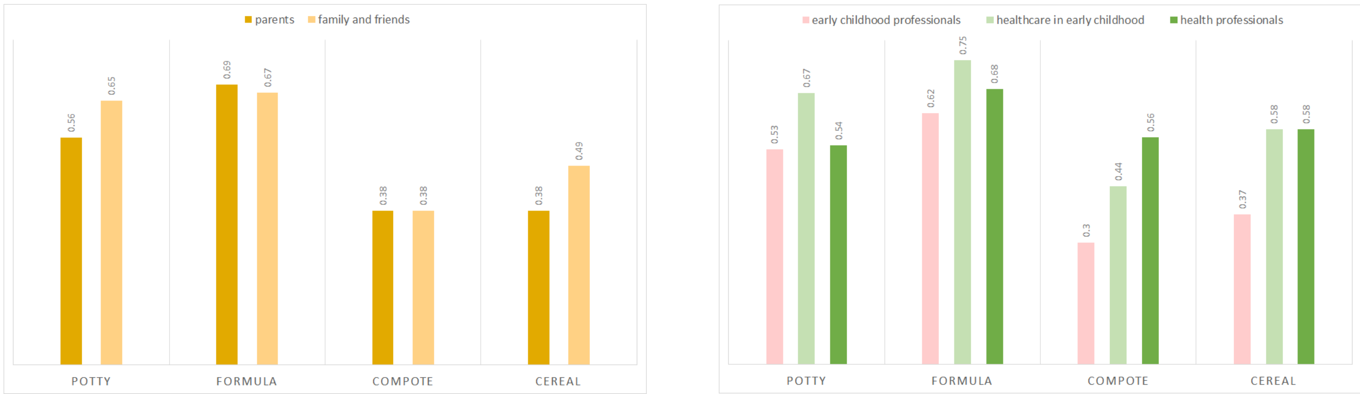


Figure 4. (**a**) Parents and families' attitudes towards chemical hazards. (**b**) Professionals' attitudes towards chemical hazards.

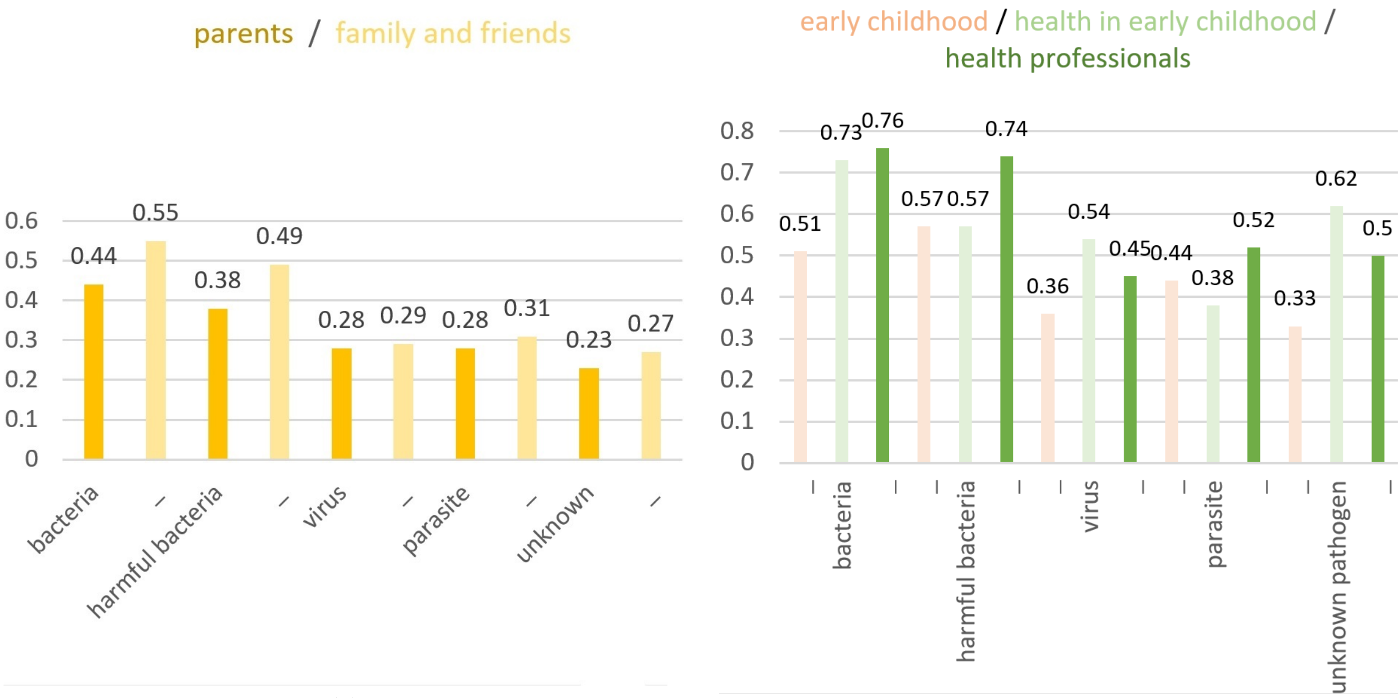
Similarly, differences in collective attitudes regarding types of food, for chemical safety, are displayed in Figure 5a,b for parents and families and for professionals of early childhood and health, respectively.



(**a**) (**b**)

Figure 5. (**a**) Parents and families' attitudes regarding chemical safety in different types of food. (**b**) Professionals' attitudes regarding chemical safety in different types of food.

The same trends can be observed in the results obtained for microbiological contaminants, displayed in Figure 6.



(**a**) (**b**)

Figure 6. (**a**) Parents and families' attitudes towards microbiological hazards. (**b**) Professionals' attitudes towards microbiological hazards.

Overall, the rankings of safety hazards follow the same trends, reviewed in Section 3.3. However, some differences between audiences are worth noting:

- According to the collective attitudes, family and relatives express more concern than parents do.
- Within professionals, a clear difference can be highlighted between the perceptions of early childhood professionals on the one hand, and health professionals, on the other hand. Early childhood professionals' collective attitudes are very similar to the

parents' ones—yet higher for agricultural contaminants, for which their collective attitudes are similar to the group "family and relatives", and somehow higher for unknown chemical hazards.

- Health professionals show a distinct profile. Their level of concern is much higher, and significant, for all categories of contaminants. The same observation can be made for the different types of food. Their ranking of hazards is somehow different from the general population: although agricultural contaminants are also top-ranked, environmental contaminants come next, then packaging and unknown contaminants. The latter strongly differs from the general population. Industrial processes, then fraud, yet significant, come last.
- Finally, we can notice that general health practitioners and health professionals specialized in early childhood show very similar concerns, except for unknown and fraud chemical contaminants, for which specialized health professionals have higher concerns, especially the younger ones. This is reversed for microbiological contaminants, where general health practitioners have higher collective attitudes.
- Gender differences can be highlighted, since women show higher concern than men. The difference is slight but systematic over the categories of contaminants and foods, apart from fraud and process-induced contaminants where concerns are equivalent. Differences regarding parents' concerns in relation to their level of education was not significant in our sample.

3.6. Are Safety Concerns Connected with Other Sustainability Concerns?

The objective of this section is to investigate whether a concern expressed by a respondent is usually isolated, or if aware respondents tend to concentrate several food-related concerns.

Strongly positive correlations were established between the priority level of the "contaminant-free" criterion when choosing an infant meal, and the priority levels of the other criteria when choosing an infant meal apart from price and ease-of-use, namely "balanced food", "allergen-free", "educating", "environment-friendly", "adapted to the child's capabilities" and "limiting waste". Moreover, the GLM revealed that the priority levels of the "balanced food", "allergen-free", "educating", and "environment-friendly" criteria when choosing an infant meal enable to predict the priority level of the "contaminant-free" criterion when choosing an infant meal with a 71% probability of correct prediction.

The cooking and purchasing habits are also connected with the priority level of the "contaminant-free" criterion when choosing an infant meal. People who often prepare homemade meals for the child, and those who often chose organic food, tend to express a higher priority level for the "contaminant-free" criterion. People who regularly feed a baby with non-specialized (general public) food, tend to have a lower priority level for the "contaminant-free" criterion.

Regular concern about contaminants from agriculture can be predicted at 64%, and from packaging at 68%. Two essential variables in the GLM models are: priority levels of the "contaminant-free" and "environment-friendly" criteria when choosing an infant meal. Within the variables regarding the type of food given to young children, the use of organic food is a significant explanatory variable to explain concern about contaminants from agriculture.

4. Discussion

The study of parents' choices for their young children—under 3 years old—has been relatively little explored in the literature on consumer behavior in marketing research. The authors of [56] investigated the choices of young parents reconciling modern lifestyle and health risks, for homemade meals or baby food, with a focus on organic food. The study highlighted that parents, and especially mothers, have a high concern about the quality of food bought for their young children, higher than for the rest of the family, which may enhance mistrust towards the food products proposed on the market. According to [56], special attention is paid to the safety and nutritional adequacy of food. This is confirmed by the present paper, which hence complements these results with further investigation on the safety issues that most worry infant food users and on audience heterogeneity.

Apart from the infant food sector, recent studies on food choice priorities for the general population also showed a clear predominance of health concerns [19]. Nevertheless, the lower priority declared for practical aspects such as ease-of-use and price, is to be interpreted with caution, including in the present paper. Indeed, in [56], practicality is mentioned as the first reason for buying potties to replace homemade food (for 28.8% of interviewees), and price as the second limitation for buying them (for 52.6% of the interviewees). At the same time, switching from conventional potties to organic ones is explained by health, environment and taste quality. This apparent contradiction may be explained by the fact that initial access to a new consumption habit, e.g., the use of ready-to-use infant food, is conditioned by practical aspects, then changes within this new habit respond to different rules [48].

Our results show consumer concern about microbiological risks is lower than for chemical risks, although high for infant formula, which was involved in industrial microbiological contamination in France in 2017 [57,58]. Coherent with this observation, the literature shows home food is associated with consumer self-confidence and outdoor food with low consumer confidence, although consumer handling is known as one of the most important contributors to microbiological risks [59,60].

Among chemical risks, agriculture is most questioned, which is in line with the conclusions of [61], stating most people who distrust the food supply chain worry about agricultural practices such as pesticides. Packaging is also questioned, possibly related to bisphenol A and other plastic contaminant issues as phthalates and melamine, which often come out [58]. The use of bisphenol A has been forbidden in food packaging since 2015 [62], but this substance and its substitutes continue to worry consumers [12]. Environmental contaminants raise fewer questions in our study, apart from health professionals, although heavy metals such as lead or mercury have frequently appeared in alarming literature in the United States [63,64] and in Europe [58]. Similarly, industrial processes or fraud are mentioned relatively rarely—apart from health professionals—despite formula with fraudulently introduced melamine in China in 2008, or recently, infant formula accused of containing mineral oil [65,66], which caused real outcries. Most likely as a consequence of the various safety scandals it overcame, infant formula is the food product that raises the most mistrust, the second one on the list being potty with vegetable and fish. For the latter, studies underline chemical contaminations due to fish they contain [67].

Nevertheless, safety crises are not the only factor that may explain mistrust in infant formula. Indeed, the suspicion brought by the various recurrent scandals involving infant formula must be considered with regard to the strong recommendation messages in favor of infant formula until the age of one [68,69], in order to avoid digestive troubles and young children exposition to chemical contamination such as dioxins [12]. At the same time, exclusive breastfeeding is recommended as the best alternative up to the age of six months by the World Health Organization and the Food and Agriculture Organization of the United Nations [70], rather than infant formula. In terms of composition, infant formula is synthetized from skimmed, pasteurized and diluted cow milk to which manufacturers add lactose, glucose, vitamins and other nutrients to approach breast-milk composition [71]. The market proposes a wide variety of product formulations [71]. In the meantime, consumer demand for naturalness and minimal processing in ready-to-use food is growing, and this is all the more valid when parents have to select food for their baby [56]. In this context, the image of infant formula as being an artificial product moves it away from the harmless and healthy expectations associated with naturalness. Finally, the modalities of preparation of infant formulas may lose consumers. The type of water used [72,73] and security rules to prepare the beverage [74] have been constantly discussed in order to avoid contaminations, especially *Cronobacter* and salmonella, the main microbiological risks of infant formula [75]. It is strongly recommended not to reconstitute the milk in advance, yet official sources mention that in exceptional circumstances, reconstituted milk can be kept in the coldest part of the fridge [76], which shows an appreciable effort to propose practical and realistic guidelines but can be misleading for users.

Considering, on the one hand, infant formula scandals, breast-milk recommendations, avoidance of synthetic products, misleading variety of infant formulas on the market, and serious handling precautions needed, and on the other hand, strong recommendation in favor of infant formula from reference authorities and pediatricians, all the elements are brought together to cast doubt on the choice of infant formula for young children. Such perceived contradictions, known as cognitive dissonance [77], result in mental discomfort. In food consumption, cognitive dissonance has been shown to generate uncertainty and to increase perceived risk, which leads to a need for consumer reassurance [78]. The role that demonstrating authenticity may play in relieving those concerns has been investigated in [79]. Hence, special attention has to be paid to communication regarding this food product.

5. Conclusions

Our work has applied recent AI-based survey analysis methodologies with the dual goals of investigating users' perceptions of infant food safety and of exploring differences between two societal target groups: the household level, and the level of childhood and health professionals who constitute a primary reference for families.

We observed the following main results:

- Within sustainability concerns, the absence of contaminants comes first, followed by the nutritional criterion.
- The highest safety concern is for contaminants from agricultural practices such as pesticides, followed by contaminants from packaging such as plastics, then by bacteria causing low-to-moderate digestive disorders.
- Among the four food models considered, powdered infant formula cause the most concern, followed by potties with vegetable and fish.
- Differences between societal target groups may be noted:
  - At the household level, family and relatives express more concern than parents. Gender differences can be highlighted, since women show higher concern than men.
  - Within professionals, a clear difference can be highlighted between the perceptions of early childhood professionals on the one hand, very similar to the parents' ones, and health professionals, on the other hand. Health professionals show a distinct profile. Their level of concern is much higher, and significant, for all categories of contaminants and foods. Their ranking of hazards is somehow different from the general population and higher for environmental and unknown contaminants.

A limitation of the study lies in its format—online—which might over-represent the young, especially in the "family" group (parents excluded). The results will thus need to be confirmed through complementary and contrasted strategies such as interviews and web mining, etc.

A practical implication of these results concerns infant formula, which is the food product that raises the most mistrust. Misleading information due to contradictory messages seems to be causing doubts on the use of infant formula for young children. Dissonant information is known to increase perceived risk, generating a need for consumer reassurance. Hence, special attention has to be paid to communication to relieve concerns regarding this food product, which is strongly recommended by reference authorities.

Confirmation of these results should also lead to policy recommendations in order to (i) take into account users' priority concerns in risk management, in particular for chemical contaminants, which cause the most concern, (ii) increase most users' awareness of safety hazards, since important differences are observed between target groups, and (iii) extend infant food safety requirements to non-specialized food, since the use of "general public" food products is widespread before the age of three.

At the household level, perceptions of food safety are only one side of the coin, expressing consumer expectations. Obviously, consumers have a say in the matter of protecting their rights and their children's rights to safe food. On the other side, they also have a part in the responsibility of collectively ensuring the safety of foods. Therefore, domestic practices should also be taken into account in the balance to set the priorities regarding safety hazard focus in infant food. This is the next step of this work, which is intended to be both enlarged to Europe and extended to the investigation of hazards bound up with domestic habits regarding infant food.

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Informed Consent Statement: Informed consent was obtained from all respondents involved in the study, stating the absence of collection of any personal data allowing for identification of respondents, and providing information on the project and on the use and storage of the data (Deliverable D8.5 of European Union's Horizon 2020 research and innovation program 861917, February 2021).

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