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Are home practices safe? Furan mitigation in infant food handling☆

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ABSTRACT

The general health and wellness of citizens, as well as the long-term competitiveness of food companies, depend on the availability of products that meet the demand for safe, healthy, tasty, and sustainable food. This requires the collective effort of all actors involved in the food chain, including at the home level. Furan is a potential cancer-causing chemical, part of volatile organic compounds, that forms when food is heated, yet evaporates easily. It poses a significant health risk, especially in infant foods. Commercial infant food jars have been identified as a primary source of furan exposure, which raises concerns due to infants' higher vulnerability. This study (i) investigates the most common ways people in Europe handle commercial vegetable-based infant food jars at home, (ii) analyses the impact of these practices on furan levels in relation to scientific literature, and (iii) explores factors that explain consumer concerns about chemicals formed during food process, using a machine learning method and data from a survey of 3585 European consumers as part of the 'Safe Food For Infants' (SAFFI) EU-China project. The results highlight some common European home practices that deserve further attention regarding the mitigation of furan (and derivatives) in food: using the microwave to reheat food, usually covering the food and not stirring it while reheating. Consumer concerns about chemicals formed during food process are linked to environmental factors (country, infant's age), habits about organizing infant meals (how long meals last and how long unopened baby food is stored), individual factors (responder's age and education level), and habits about reheating infant food (how long food is reheated and left to stand afterwards). This study emphasizes the importance of appropriate home practices and of enhanced risk communication to reduce both risk and consumer concerns.

1. Introduction

Consumer perceptions and awareness of the risks associated with infant foods play a pivotal role in influencing home practices (Aline et al., 2023; Hässig-Wegmann et al., 2024; Kurtz & Thomopoulos, 2021a). Furan, a volatile organic compound formed during the thermal processing of food, has emerged as a contaminant of concern, particularly in vegetable-based infant food jars due to their compositions and sterilization treatments (Sandjong Sayon et al., 2024). As a possible human carcinogen, as classified by the International Agency for Research on Cancer (IARC, 1995), furan poses a significant risk due to its presence in commercially prepared infant foods, and reducing furan exposure in infant foods is a critical public health priority (EFSA, 2017). Alongside advances aimed at developing formulations or processes on an industrial scale that generate less furan (Anese et al., 2013; Torrents-Masoliver et al., 2022), research must be carried out on home practices that will limit or eliminate its formation in order to guide recommendations intended for consumers (ANSES, 2016). However, there is currently limited understanding of how common home practices for handling and reheating commercial infant food jars impact the mitigation of furan, making it essential to investigate these practices in light of existing scientific knowledge.

Parents and caregivers appear motivated to make informed decisions about infant food preparation but may lack clear guidance based on

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scientific evidence (Franc-Dabrowska et al., 2021; Meysenburg et al., 2014; Stenger et al., 2014). Misconceptions or lack of knowledge about the conditions under which furan forms, and how to mitigate its presence, can lead to practices that unintentionally increase exposure. Understanding how parents and caregivers perceive the risks related to furan, and their attitudes toward different reheating methods, is essential to developing effective strategies for risk communication and behavior change.

While previous works have studied, on the one hand, the risk related to furan in food through analytical studies (EFSA, 2016; Fromberg, 2014), and on the other hand, consumer perceptions (Hässig-Wegmann et al., 2024; Kurtz & Thomopoulos, 2021a), a joint analysis has never been carried out until now. In addition, the frequency and impact of each step performed at home in real practices were not analyzed. This study adds depth to existing knowledge through its interdisciplinary approach, combining systematic decomposition of home practices, integration of survey data, and consumer insights using machine learning. The study aims to identify and to evaluate the relevance and effectiveness of the most common domestic practices for the mitigation of furan and its derivatives during the use of commercial vegetable-based infant food jars, in light of current scientific understanding. Additionally, it seeks to explore consumer perceptions of the risks associated with process-induced toxicants in infant foods. By examining both the scientific and social dimensions of this issue, this research will contribute to a more comprehensive understanding of the potential for reducing furan exposure through home practices. Ultimately, the goal is to inform evidence-based recommendations that can guide safer practices in the home, ensuring the health and safety of infants while addressing parental concerns about food safety.

2. Material and methods

2.1. Designing information collection

The design of the information collection methodology relies (i) on the collection and organization of information in four types of features denoted as “axes”, and (ii) on the determination of relations between these axes.

(i) The four axes include:

- Axis 1: The chronological steps of home handling that may affect the safety of the food product, based on scientific expertise (see e.g. Buche et al., 2019; Thomopoulos et al., 2009 for systemic methods based on step-by-step analysis such as decomposition into unit operations). Each step can take different modalities, i.e. possible choices made by users at home. In the case considered, these steps are composed of the following actions:
  - ✓ reheating or not the infant food jar (modalities: yes/no),
  - ✓ container used for reheating (modalities: original packaging, other container than packaging, in a pan directly),
  - ✓ stirring or not the food before reheating it (modalities: yes/no),
  - ✓ means of reheating (modalities: water bath, microwave, bottle warmer, hot plate, oven, other),
  - ✓ covering or not the food while reheating (modalities: yes/no),
  - ✓ stirring or not the food while reheating (modalities: yes/no),
  - ✓ stirring or not the food after reheating it (modalities: yes/no),
  - ✓ Leaving or not a standing time before giving the food to the infant (modalities: yes/no),
  - ✓ covering or not the food during the standing time (modalities: yes/no).
- Axis 2: The food safety properties studied. In the case considered, these are: furan (and derivatives) mitigation.
- Axis 3: Handling habits at home reported by consumers.
- Axis 4: The perceptions expressed by consumers regarding the food safety properties studied. In the case considered, these perceptions consist of the concern expressed regarding process-generated contaminants, which furan and its derivatives are part of.

(ii) The relations between the axes include:

- Relation 1: Frequencies of modalities for each step (axis 1) in home habits (axis 3).
- Relation 2: Relevance of most frequent step modalities (axis 1) for the food safety properties considered (axis 2).
- Relation 3: Association level of home habits (axis 3) with safety perceptions (axis 4).

The rest of the methodology aims to explore these three relations.

2.2. Collecting consumer home practices and perceptions

Within the ‘Safe Food For Infants’ (SAFFI) Europe-China project (Engel et al., 2022), an online survey was carried out among a panel of 3585 European citizens on perceptions regarding infant food chemical and microbial safety, and home practices concerning four store-bought infant foods (powdered infant formula, sterilized vegetable mixed with fish, infant cereals, fruit puree). The survey included questions investigating the 9 steps indicated in Section 2.1, with the corresponding modalities in the possible answers. In addition, questions about the perceptions of infant food safety explored the expression of concerns about different categories of hazards, among which process-induced contaminants such as furan and its derivatives. The questions and the results of the survey are provided in Thomopoulos et al. (2024).

To limit consumer reporting bias (Groves et al., 2009; Kalton & Schuman, 1982), several precautions were taken in the survey design: using closed questions to avoid response variability; avoiding questions with obvious “good answer” that could influence the responders; proposing a balanced range of answers, such as Likert-scale. In addition, the survey was translated in the native languages of the seven countries studied, to ensure language understanding. Finally, it was tested at a smaller scale (Kurtz & Thomopoulos, 2021b; Thomopoulos & Kurtz, 2022) prior to launching.

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 N°861,917, February 2021).

2.3. Critical analysis of Most frequent practices

A synthesis of the arguments from the scientific literature is provided to highlight the pros and/or cons of most common practices regarding furan evolution in the food product. We followed the method of (Thomopoulos, 2018; Thomopoulos et al., 2020) that has proved efficient in various applications (Vivas et al., 2022; Sandjong Sayon et al., 2022; Abou Jaoudé et al., 2022; Thomopoulos et al., 2018; Salliou & Thomopoulos, 2018). For each practice, the main argumentation stemming from the scientific literature is provided, indicating the main conclusions – in favor or not of the considered practice with regard to furan evolution –, information source as well as the reasons provided, then summarized using a color code.

2.4. Understanding user perceptions using machine learning

In Tonda et al. (2022, 2023), a machine learning method based on the Random Forest (RF) (Breiman, 2001) classification algorithm was used to determine the factors that best explained concerns about food risk, with a data set produced by a large-scale survey. A similar approach is applied in this study, with the purpose to identify factors that best explain concern about process-induced toxicants, such as furan and its

derivatives. The principle of this method is defined as follows.

The objective of this step is to explore the question: 'What variables best separate individuals who express concerns about process-induced contaminants in infant food, from those who do not?'. Therefore, we create two classes of responders, by separating those who declare to have regular thoughts about this issue (class 1, including 383 responders), from the other responders (class 0, with 824 responders): this is asked as a specific sub-question (Q_38) in the survey (see Thomopoulos et al., 2024). This sub-question is worded as follows: 'How often do you wonder if the child's meals contain these contaminants when you choose or prepare them? [Substances generated during industrial processes such as cooking (furan, etc.)]'. We then train a RF

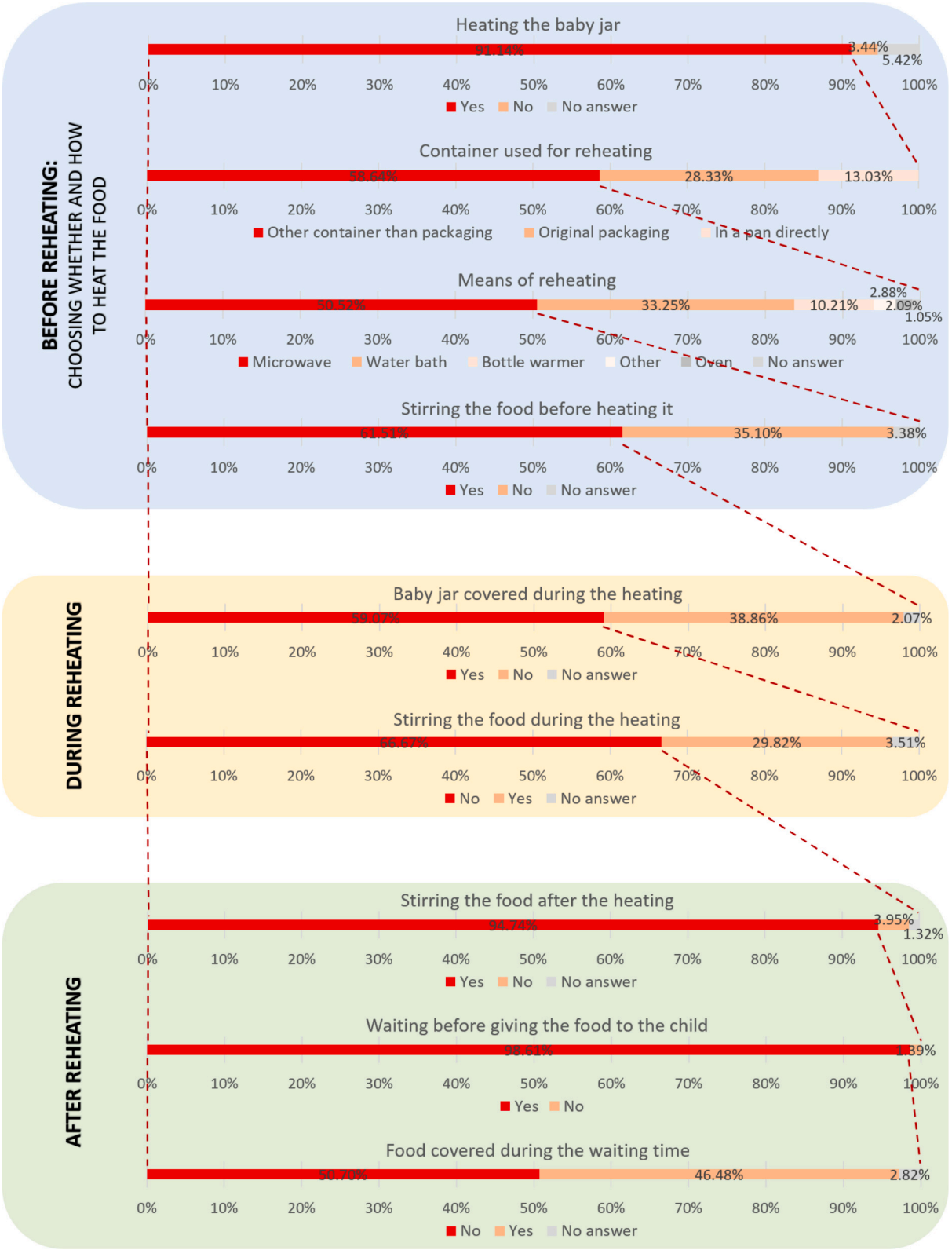

Fig. 1. Most frequent sequence for handling infant food jars at home.

classifier to separate the two classes based on the information contained in all other questions than risk perception in the survey. After the classifier is trained, we analyze the features (i.e. answers to the other questions in the survey) that the classifier ranked as the most important for the classification procedure, in order to interpret them as elements that might separate the two types of responders. The ranking of the features in RF selected for this study is performed using the Gini importance metric (Breiman et al., 1984).

Validation of the RF method is both internal and external. Internal validation is performed through cross-validation (10-fold in this study). The purpose of cross-validation is model checking. In the RF algorithm, the outputs of multiple decision trees are combined to reach a single result, each tree being constructed using a different bootstrap sample from the original data. In addition to this, cross-validation uses multiple training and testing cycles, minimizing the impact of data variability, while accounting it in performance evaluation. External validation is achieved by comparing the results obtained with previous works, which is addressed in Section 3.3.

3. Results and discussion

3.1. Food handling habits in domestic practices

The results presented refer to 1162 survey answers, corresponding to the number of responders who declare themselves as infant food jar users, regularly or occasionally.

The most frequent scenario for handling infant food jars at home is described in Fig. 1. Considering the handling steps chronologically:

- In 91.14 % of responses, the infant food jar is reheated.
- Among these, in 58.64 % of responses, the content of the infant food jar is transferred into another container than the original packaging.
- Among these, in 50.52 % of responses, the infant food is reheated in the microwave.
- Among these, in 61.51 % of responses, the food is stirred before reheating.
- Among these, in 59.07 % of responses, the food is covered while reheated.
- Among these, in 66.57 % of responses, the food is not stirred during the reheating.
- Among these, in 94.74 % of responses, the food is stirred after the reheating.
- Among these, in 98.61 % of responses, there is some standing time before giving the food to the infant.
- Among these, in 50.70 % of responses, the food is uncovered during the standing time.

Preliminary results obtained in the 'Safe Food For Infants' (SAFFI) Europe-China project provide insight into food handling habits in China and highlight some differences between the above results obtained in Europe and those obtained in China. The main difference to be noted regards the reheating process, which is mostly achieved with water-bath in China (versus microwave in Europe). Moreover, in the responses obtained in China, the food is usually not stirred before reheating. Responses to the other steps show similar trends both in Europe and in China.

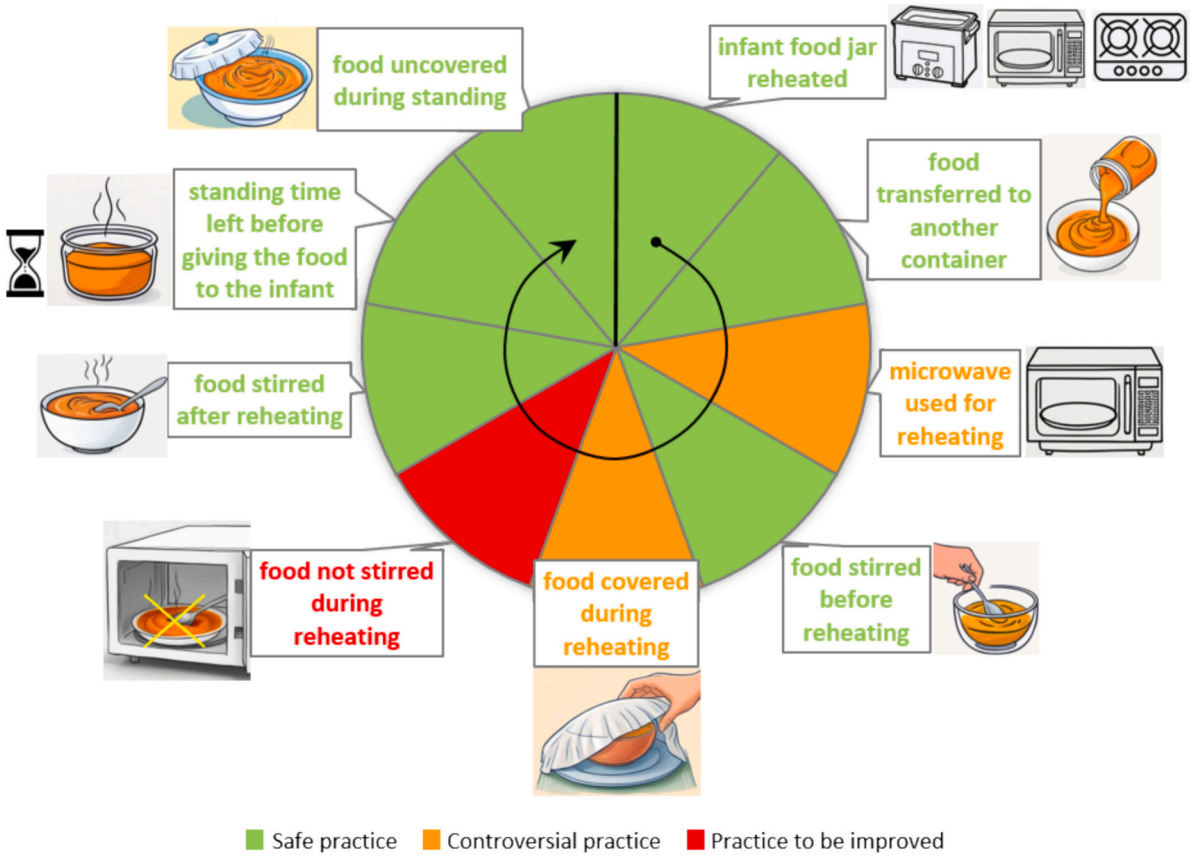

Fig. 2. Assessment of most common handling practices from the viewpoint of furan mitigation. The color code used is to be interpreted as follows: green is used when the practice is considered furan-safe in view of literature conclusions; orange is used when literature conclusions are mitigated regarding the practice; red is used when the practice is considered not to be ideal regarding furan in view of literature conclusions. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

3.2. Critical analysis of Most frequent practices

Fig. 2 depicts through a color code the relevance of most frequent handling practices from the viewpoint of furan mitigation. Arguments and explanations for this assessment are discussed in this section. The results presented concern home practices in Europe and, in most cases, also apply for the preliminary results obtained in China, with some nuances which are indicated in the paragraphs analyzing the corresponding practices.

Let us note that, as in any knowledge engineering approach, this analysis is based on the current state of literature, which is still limited and evolving, with numerous parameters involved, and that the conclusions are subject to future updates.

Reheating the infant food jar.

The pros. Table 1 summarizes results from the scientific literature. Literature suggests that reheating the food is a necessary condition to enhance furan evaporation from food, either through the temperature effect by itself for moderate temperatures exceeding 60 °C, or in combination with other practices (stirring in particular, see Sandjong Sayon et al., 2024) as discussed below. Temperature appears to act as an accelerator of furan evaporation. Optimal reheating temperatures still need further investigation, as well as the food matrix effects (such as lipid content, see Rahn et al., 2019; Van Lancker et al., 2009). It might also be that new furan generation during the reheating is suspected to co-occur (Lachenmeier 2009; Hasnip et al., 2006).

Transferring the food to another container than the original packaging.

The pros. Several authors have highlighted the relevance of increasing the evaporation surface in order to reduce the levels of furan. Lachenmeier et al. (2009) noted the infant food and opening of the jars exposes only a relatively small surface area. Sandjong Sayon et al. (2024) recommends the transfer of the jar content into a bowl in order to extend the exchange surface during stirring, while Roberts et al. (2007) observed a slight decrease of furan contents when foods were left to stand on plates, which was attributed to the volatility of furan.

Using microwave to reheat the food.

The cons. Microwave reheating is known to generate hardly-predictable temperature distributions inside the food (Albuquerque, 2019), which can lead to local overheating and under-heating phenomena. Thus, in cold spots, the reheating temperature might not reach the desired target temperature to enhance furan evaporation. This heterogeneity of treatment makes the microwave process difficult to control. For this reason, Fromberg et al. (2009) indicate that higher proportions of the initial amount of furan will remain in the food item, if the food is reheated to a relatively low temperature in a microwave oven. The results of Roberts et al. (2007) are also in line with this observation.

These considerations are less relevant for home practices in China, where the majoritarian means of reheating used appears to be water-bath, and the use of microwave less prevalent than in Europe.

Mitigating remarks. Fromberg et al. (2009) emphasizes that the changes in the furan concentrations seem to be more influenced by the maximum temperature achieved by the reheating process, than by the reheating process itself. Practices that contribute to reduce temperature heterogeneity within the food product (stirring in particular) are addressed below.

Stirring the food before reheating.

The pros. During microwave treatment, the dielectric properties of the food determine the interactions between matter and electromagnetic radiation (Motasemi & Afzal, 2013). Consequently, the heterogeneous distribution of microwave energy in the volume of the food product is responsible for the generation of hot spots and cold spots. Stirring the jar prior to reheating homogenizes the food product, thus moderating the heterogeneous temperature distribution and decreasing the risk of furan retention in cold spots.

Covering the food during reheating.

Table 1
Effects of reheating the food products on furan content according to literature data.

Literature positioning	Specific conditions	Observations	Sources
In favor of reheating: temperature promotes furan evaporation	Reheating at medium temperature around 60 to 100 °C during usual reheating time	Furan loss up to about half the original content was found during reheating. A correlation was observed between the maximum temperature reached and the furan loss for temperatures raising from 68 °C to 102 °C, while no loss was observed if no reheating was applied. Other papers report results in line with these findings.	Fromberg et al. (2009, 2014)[1] Roberts et al. (2007)[2] Kim et al. (2009, 2023)[3] Goldmann et al. (2005)[4] Zoller et al. (2007)[5] Palmers et al. (2015)[6]
	Reheating at moderate temperature around 40 °C during usual reheating time	No significant furan loss can be stated: Although the mean values of furan levels are shown to decrease with reheating, result uncertainty increases –standard deviation (Sandjong Sayon et al., 2024) or measurement uncertainty including uncertainty due to both analysis and reheating (Hasnip et al., 2006)– so that no significant furan loss can be concluded.	Sandjong Sayon et al. (2024)[7] Hasnip et al. (2006)[8] Lachenmeier et al. (2009)[9]
	No reheating, long standing time (1 day) at 4 °C	Furan loss from none up to half the original content.	Kim et al. (2009)[3]

[1] A wide range of foods was tested, including five ready-to-eat foods intended for infants, three of them vegetable-based (infant food with carrots and maize; infant food with tomato in glass; infant food with peas, banana and rice in glass), and two fruit-based.
[2] Various foods, including canned and jarred infant foods (e.g. canned carrot and lamb; jarred pumpkin, swede and lamb).
[3] Various foods, including infant foods such as baby soup; pumpkin.
[4] Various foods, including jarred infant foods containing cooked vegetables.
[5] Various foods, including infant foods containing either meat without vegetable, or vegetable with/without meat, or fruit.
[6] Seven varieties of shelf-stable, vegetable-based purees.
[7] Three commercial vegetable-based infant meals (sterilized jars containing respectively vegetable alone, vegetable with fish, and vegetable with meat).
[8] Various foods, including infant food with vegetable and chicken, and with vegetable alone.
[9] Various infant foods, including several commercial infant food jars containing vegetable with or without meat.

The cons. Covering the food prevents the evaporation of furan during the reheating. In studies such as Kim et al. (2009), significant losses of furan were observed when opening a lid and when reheating foods without a lid.

Mitigating remarks. Nevertheless, it is unclear from the literature whether the use of a non-hermetic lid (as usually recommended for microwave reheating to avoid the drying of the food) is adequate to

allow for efficient furan evaporation, or if it restricts it. In Hasnip et al. (2006), considering measurement uncertainty, no conclusion could be made regarding the effect of using no lid, a plastic lid, or a glass lid on furan loss.

In the absence of conclusive studies, considering that the use of a non-hermetic lid is efficient to reduce the drying of the food through water evaporation, it can reasonably be hypothesized that it may also restrict furan evaporation.

Recommendations regarding this practice are also relevant for the Chinese public, notwithstanding differences in the means of reheating most commonly used.

Not stirring the food during reheating.

The cons. For two reasons it can be recommended to update this habit by introducing stirring step(s) during microwave reheating: 1/ To homogenize the food temperature between hot spots and cold spots that may have started to occur (Albuquerque, 2019), thus decreasing the risk of furan retention in cold spots; 2/ To enhance furan evaporation. Stirring has been shown to be efficient to favor furan evaporation from reheated food (Rahn et al., 2019; Roberts et al., 2007; Sandjong Sayon et al., 2024).

Recommendations regarding this practice are also relevant for the Chinese public, notwithstanding differences in the means of reheating most commonly used.

Stirring the food after reheating.

The pros. As indicated in the previous paragraph, stirring is recommended since it has been shown efficient to enhance furan evaporation from reheated food.

Leaving a standing time before giving the food to the infant.

The pros. The conclusions of Roberts et al. (2007) sum up well the known impact of post-reheating standing on furan: "Furan decreased slightly in foods on standing before consumption, but did so more rapidly on stirring".

The cons. There is thus little effect of standing alone. In the very recent study of Sandjong Sayon et al. (2024), the drop in furan concentration during standing was observed for one infant food jar (out of three) and only during the first minute of standing, while the effect of stirring was confirmed predominant. According to Fromberg et al. (2009), furan is relatively stable in reheated foods left for cooling, since the losses of furan observed were insignificant.

The standing time is thus recommended combined with stirring (Sandjong Sayon et al., 2024).

Leaving the food uncovered during the standing time.

The pros. As previously discussed, leaving the food uncovered is necessary to permit furan evaporation from the food product.

In view of the differences in food handling habits in China compared with Europe, some differences and some common points can be noted in the recommendations. The reservations expressed above regarding the use of microwave reheating are less prevalent in China due to the majoritarian use of water-bath. Two recommendations remain relevant for the Chinese public: the recommendation to let the food uncovered during reheating, and the recommendation to stir the food during reheating (in addition to post-reheating stirring which is commonly practiced), for the reasons expressed above.

These differences have significant implications for global risk communication strategies, especially in the context of food safety recommendations. They underscore the importance of adapting food safety guidelines to local practices and taking into account cultural preferences. Global risk communication will thus have to be flexible enough to account for both differences and commonalities in food handling practices, but also to use appropriate and effective channels.

Finally, it is important to remind that the above analysis of practices is carried out exclusively from the viewpoint of furan mitigation. From other viewpoints (e.g. microbial, nutritional, ecological, etc.), the recommendations could be different, and even possibly conflicting with those regarding furan. For example, the first practice discussed –reheating the infant food jar or not– can be examined in relation to food flavor, texture, nutrient loss, etc. (IFST, 2022). While reheating would be also beneficial to the development of a pleasant flavor and texture, it could somewhat reduce nutritional value by modifying vitamin level and protein activity. The interested reader may refer to Bourguet et al. (2013) for a methodological study of different viewpoints in the food sector.

3.3. Relation between home practices and process-related risk perception

The RF classifier shows a mean accuracy on test of 0.79 and a F1-score of 0.70 in a 10-fold cross-validation. After training the RF classifier, it is possible to sort the features it used by their Gini importance, or in other words, their relative contribution to the quality of the prediction. Fig. 3 shows the features ranked by decreasing Gini importance. We then fixed an arbitrary threshold of Gini importance (>0.03) to perform a deeper analysis, which resulted in a total of 8 features. The survey questions corresponding to these top-ranked features are detailed in Table 2, in the same order as in Fig. 3.

Three types of characteristics appear as explanatory factors of the level of concern about process-induced contaminants in food:

1) Factors that can be interpreted as enhancers of responder's concern regarding safety (i.e. factors amplifying concern).

- External factors: The cultural environment and in particular the country of the responder (Q_88, ranked second) have been shown to influence the level of concern declared by the responder (EFSA, 2022; Thomopoulos et al., 2024). Differences in various safety concerns have been observed between European countries and in addition, in some countries responders tend to more easily claim higher concern, which can be considered as a cultural factor. Another important external factor is the age of the infant (Q_5, ranked third), since lower ages and thus higher vulnerability to hazards explain higher parents' concern.
- Internal factors: Characteristics of the responder herself/himself also influence the level of concern. Lower levels of studies (Q_89, ranked 5th), and higher responder ages (Q_86, ranked 6th) appear as explanatory factors of concern according to the results obtained.

2) Factors that can be interpreted as indicators of responder's global attention paid to the infant's meals. Long durations of the infant's meals (Q24, ranked first) can be interpreted as emphasis given to the progress of the meal. They might also have a cultural basis. Pre-planned storage of the infant food (Q_26, ranked fourth) is another possible sign of concern.
3) Factors that can be interpreted as indicators of responder's awareness about process-induced toxicants. The last –but highly relevant to our topic– type of factors involves food handling practices that have connection with process-induced toxicants. Habits regarding reheating times (Q_17, ranked 7th) and post-reheating standing times (Q_18, ranked 8th) are part of such factors that tend to suggest responder's awareness about food safety in everyday food handling habits. Such results involving the level of knowledge about food are in line with the conclusions of Tonda et al. (2023) which addressed awareness about food risk for the general public, non-limited to infant food. Nevertheless, it is notable that process-induced toxicants do not appear as consumers' priority concern, according to several recent studies (EFSA, 2022; Kurtz & Thomopoulos, 2021a; Thomopoulos et al., 2024), compared with other chemical contaminants.

4. Conclusion

Through an original approach for integrating both scientific analysis and consumer perception data, this study provides valuable insights into the domestic practices for handling infant food jars in Europe, focusing on their influence on furan mitigation and consumer perceptions of

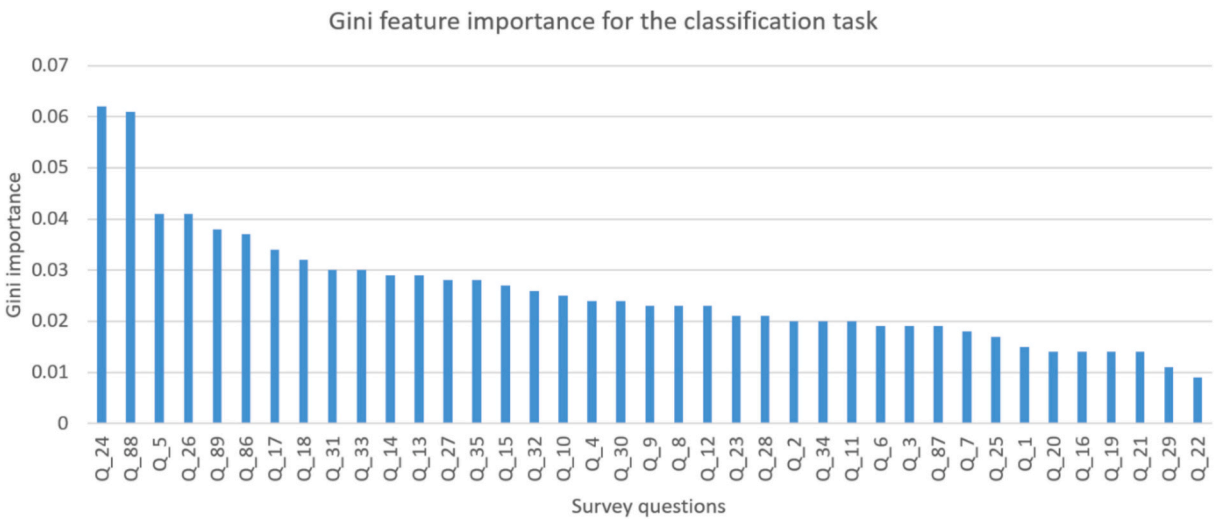

Fig. 3. Gini feature importance for the classification task.

Table 2
Most relevant explanatory questions identified.

Id	Question	Type of correlation with Q_38
Q_24	How long (in minutes) does the child's meal last at most?	positive
Q_88	In which country are you living?	NA
Q_5	How old is the child?	negative
Q_26	How long do you usually keep the pack of powdered infant formula / infant cereals, before opening?	positive
Q_89	What is your level of study?	negative
Q_86	You are: [chose age category]	positive
Q_17	How long (in minutes) do you usually heat the baby jar?	negative
Q_18	How long (in minutes) do you usually wait before giving the heated baby jar to the child?	positive

process-induced contaminants. Differences with most common practices in China are also discussed. The findings reveal that while European common household practices such as microwave reheating might contribute to furan retention, simple modifications—such as leaving the food uncovered and intermediate stirring—can enhance furan evaporation. Additionally, the study highlights the importance of tailoring risk communication efforts to parents and families, as concern about process-induced toxicants varies by country, infant's and responder's ages, education level, and meal management habits.

Moving forward, the results support the need for further investigation into optimal reheating methods and temperature settings to maximize furan mitigation while balancing nutritional and safety requirements during home practices.

CRediT authorship contribution statement

Rallou Thomopoulos: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Donnelle Roline Sandjong Sayon:** Writing – review & editing, Conceptualization. **Alberto Tonda:** Writing – review & editing, Software, Methodology. **Hui Qiu:** Investigation, Formal analysis, Data curation. **Weihuan Fang:** Writing – review & editing, Validation, Supervision, Project administration. **Erwan Engel:** Writing – review & editing, Validation, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The data have been published with DOI and are cited in the article. The data deposit includes the ethics statement procedure.

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