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A trans disciplinary and multi actor approach to develop high impact food safety messages to consumers: Time for a revision of the WHO - Five keys to safer food?

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ABSTRACT

Background: A significant part of foodborne infections is caused by food eaten at home, and food safety messages are given to help consumers mitigate risk. The World Health Organisation “Five Keys to Safer Food”, developed about 20 years ago has been used with success worldwide to provide general advice on how to prepare food safely.

Scope and approach: In this commentary, we discuss how food safety messages could be updated using a holistic approach built on implementation science, considering new food consumption patterns and insights from natural and social sciences. A stepwise approach for developing and evaluating food safety messages, performed in the European project SafeConsume, is presented. The top pathogen-food combinations associated with foodborne disease in Europe were combined with common consumer practices to identify risky behaviours. Food safety messages were suggested and assessed for understanding as well as capability, opportunity, and motivation in an expert survey.

Key findings and conclusions: Overall, the food safety topics developed overlapped with those from WHO. The opportunity and motivation for changing behaviour, (e.g., choose pasteurised egg) were identified as important restrictions for uptake of messages. Also, understanding terminology, (e.g “thoroughly cooked”) was a challenge. Therefore, there is a need to be specific, without excluding other safe alternatives or make lengthy explanations. The food safety messages suggested by the expert group were considered as more likely to be implemented among domestic cooks, resulting in safer practice than corresponding WHO messages. WHO should reconsider the preventive risk communication based on new knowledge and challenges.

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1. Background

The most used and widespread information to consumers about how to procure, prepare and store food safely is the World Health Organization (WHO) “Five Keys to Safer Food”. In the early 1990s, Ten Golden Rules for Safe Food Preparation were developed and published by WHO, and ten years later a simplified version, the Five Keys were developed by the Department of Food Safety and Zoonoses at (WHO) (Fontannaz-Aujoulat, Frost, & Schlundt, 2019). Aiming to change behaviour, the five keys were simple and included what to do and why to do it, in line with the best practices for risk communication at the time. The target groups were both professional food handlers and consumers, including children worldwide. The materials were developed in a one-year process involving scientists, health educators, risk communicators, and the WHO food safety advisors. These were validated in 2001 by the Joint FAO/WHO Expert Committee on Microbiological Risk Assessment (JEMRA), an independent expert body of international scientists. Since then, a wealth of scientific knowledge about pathogens and how they are transferred, multiply, and survive during food preparation has been generated together with a much wider understanding of consumers and food consumption. Also, risk communication models have evolved taking into account a broader understanding of the scope of communication and how information should be designed reduce risky behaviours (European Food Safety Authority (EFSA) et al., 2021; Kasza, Csenki, Izso, & Scholderer, 2022). Meanwhile, several factors affecting risk and risk communication, such as the food system, consumption patterns and communication platforms have changed substantially. It is therefore timely to explore how and if new insights could add to present food safety advice.

This paper discusses the present status of preventive risk communication and describes a process conducted in the European Research and Innovation project, SafeConsume, for developing evidence-based food safety messages targeting behavioural change with expected high uptake and impact for the European population. Hopefully, this opinion and the approach presented can inspire stakeholders in the food system to develop more persuasive food safety messages to consumers.

2. Foodborne infection: What is the role of consumer practices?

A large number of pathogens and foods are linked to foodborne diseases. *Salmonella*, *Campylobacter*, *Norovirus*, *Toxoplasma gondii* and *Listeria monocytogenes* were listed as the five microbial hazards contributing most to the health burden in Europe (World Health Organisation, 2015). Among these, *Salmonella*, *Norovirus* and *Campylobacter* contributed to most household outbreaks and *Listeria* caused most reported deaths in 2019 (European Food Safety Authority & European Centre for Disease Prevention and Control, 2021). Most listeriosis cases are domestically acquired, and the incidence is increasing, probably because of a larger population of elderly (European Food Safety Authority (EFSA) BIOHAZ Panel, 2018). Risk factors were identified in less than 30% of the domestic outbreaks in Europe in 2020. For strong-evidence domestic outbreaks the main risk factor for foodborne illness was inadequate heat treatment followed by consumption of contaminated unprocessed food (European Food Safety Authority & European Centre for Disease Prevention and Control, 2021). Infected food handlers (mostly by *Norovirus*), inadequate chilling, cross contamination and storage time abuse were also reported as risk factors associated with domestic outbreaks. In the report for 2021, no details about risk factors were given, but consumption of contaminated unprocessed food was on the top of the list (European Food Safety Authority & European Centre for Disease Prevention and Control, 2022) When interpreting the statistics, one should be aware of underreporting, especially for incidences occurring from homemade food (Scott, 2003; European Food Safety Authority & European Centre for Disease Prevention and Control, 2022).

The role of the consumer on foodborne illness can be supported by

data on their practices, showing that significant proportions of consumers in Europe share food purchase, storage and preparation practices that may result in foodborne infection (see Table 1). Two examples are *Campylobacter* and *Salmonella* infections acquired from chicken, which are associated with poor hygiene and insufficient cooking. In kitchen observation studies, less than half of the observed home cooks washed their hands with soap and water after touching raw chicken (Didier et al., 2021) and common ways of judging if the meat was cooked, were not accurate (Langsrud et al., 2020). Consumers that were aware of pathogens in chicken were more likely to follow best practices, indicating a need for information about the risk and how to reduce it (Moretto et al., 2021). Interventions building on the perceived control over the food handling environment may be effective in influencing consumer intentions to handle food safely, while the reinforcement of applied good hygiene practices found to be promising in modifying consumer routines (Mullan & Wong, 2009).

3. How to develop effective food safety messages?

As the last line of defence, safer consumer behaviours could have a substantial impact on mitigating the risk of foodborne infection. As these behaviours cannot be targeted through legislation, *information* is the dominant intervention targeted to consumers by national and international authorities, as well as by non-governmental organisations and the scientific society. However, information may not necessarily lead to behavioural change. As an example, Charlesworth et al. (2021) found that only 4 out of 8 food safety messages promoted in a large media campaign led to behavioural change (Charlesworth et al., 2021) and possible explanations were linked to risk perception and habits (Charlesworth et al., 2022).

To obtain a real impact on the burden of illness in Europe, food safety messages should focus on *most risky practices* (considering frequency of the practice and the probability of getting ill), and also the *most implementable practices*. To be effective, understanding consumers is crucial and applied risk communication models increasingly count on interactions with consumers and take consumer risk perception into consideration when designing risk mitigation interventions (Kasza, Csenki, Szakos, & Izso, 2022). Traditional theory within risk communication is mostly discussing psychological and cultural barriers for behavioural change (Bangboje-Ayodele, Ellis, & Turner, 2019; Jacob, Mathiasen, & Powell, 2010). A wider approach may be necessary to fully analyse the potential uptake of a message, considering not only consumers’ motivation and capability, but also their opportunity to change behaviour (Michie, van Stralen, & West, 2011). Also, lack of supporting scientific evidence of the risk is an important barrier for the efficacy of food safety messages (Gilman, Henley, & Quinlan, 2021).

A message’s power to change behaviour depends not only on the content, but also on the way the message is formulated (Egger, Donovan, & Spark, 1993). When formulating food safety messages, consumers’ common level of knowledge should be considered. Also, practice-specific advice is more efficient than general information and keeping the language simple is crucial (EFSA, 2017). The proposed behaviour should be mindful to other issues, such as food nutrition, food waste and gender-neutral messages should be formulated. Research shows that people in general prefer simple explanations over complex explanations (Chater & Vitanyi, 2003; Lombrozo, 2006, 2007), and providing too complex messaging can result in consumers following simpler, but incorrect advice instead. (Sanna, Schwarz, & Stocker, 2002). The same effect can arise from presenting negative messages (e.g., telling people what NOT to do). As time passes, the memory of the details fade and people may forget what was correct and what was wrong (Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012).

In communication aimed to change behaviour, motivational elements are often included to increase the likelihood of uptake (Abrahamse, 2020; Chambers, Chambers, Godwin, Doan, & Cates, 2020; den Akker, Cabrita, den Akker, Jones, & Hermens, 2015). Using illustrations

Table 1

Unsafe practices reported in survey or observed in fieldwork with corresponding practices that can reduce potential exposure to hazards significantly. References are given, but a full review of the literature was outside the scope of the paper.

Target practice	Safer practice	Pathogen	Frequency target practice	Reference
1. Shopping				
1.1 Procure eggs or eat eggs that are not controlled or from less safe sources, e.g. backyard eggs	1.1 Procure eggs with <i>Salmonella</i> guarantee or industrial eggs	S	26% of Europeans typically get eggs from a backyard or a directly from a farm	Scholderer (2022)
1.2 Collect bivalve mussels yourself or get from friends	1.2 Only buy from authorized sources	N	12% of Europeans get bivalve molluscs from uncontrolled sources (Market, fisherman, harvest themselves).	Scholderer (2022)
1.4 Buy Ready-to-eat food that support pathogen growth	1.4 Select products with preservatives when possible	L, S	94% of consumers ((10 European countries) do not consider preservatives when judging whether cold meats are safe to eat	Scholderer (2022)
2. Transport				
2.1 Don't pay attention to temperature and time from purchase to home	2.1 Less than 2 hours at abuse temperature	L, S	No data	
2.2 Keep raw chicken and other foods in the same shopping bag	2.2 Keep raw chicken and other raw meats in shopping bags that are separate from RTE foods	S, C	No European data. As US study reported 75% of consumers using the same bag for raw meats and other foods	Williams, Gerba, Maxwell, and Sinclair (2011)
3. Handling				
3.1 Handling raw chicken with hands/ knives/fork/cutting boards/sink that will be in contact with mouth or RTE foods	3.1a Buy chicken product that is fit for the recipe and needs no handling (e.g. ready cut chicken breast for a stew) 3.1b Clean hands, utensils or sink after being in contact with raw chicken or its juices and before using for anything else 3.1c Within the same meal preparation: Separate hands and utensils for raw chicken and RTE (bread, vegetables, fruit, ready cooked chicken) 3.1d Heat all food that accidentally was in contact with raw chicken or raw chicken juices 3.1e Prepare chicken after salad	S,C	Consumers (10 European countries) report a likelihood of 59% for washing hands after touching chicken. Consumers (10 European countries) report a likelihood of 17% report for re-use of the knife without washing it after cutting chicken and 21% for re-use of chopping board. 73% would not wash the chopping board with soap before re-using it.	Scholderer (2022)
3.2 Eat fresh produce without rinsing in water	3.2 Wash fresh produce before eating	S, N, T, C	26% of consumers 10 European countries) report they do not rinse vegetables or fruit	Scholderer (2022)
4. Cooking				
4.1 Use raw eggs from less safe sources in dishes that will not be cooked	4.1a Only use eggs that has been stored at <5 °C for dishes that will not be cooked 4.1b Modify recipes with raw eggs: Avoid eggs in recipe 4.1c Modify recipes with raw eggs: Use pasteurised egg white (buy or pasteurise yourself) 4.1d Modify recipes with raw eggs: kill Salmonella using acids for preparation of mayonnaise	S	89% of consumers do not check eggs for health marks (Salmonella free) upon purchase. 8% keeps eggs at room temperature.	Scholderer (2022)
4.2 Don't cook foods according to label (e.g. frozen fruit/berries/vegetables, sausages, dinners)	4.2 Cook "Ready-to-cook" foods according to label	L, S, N, T, C	Less than 20% always or often follow cooking instructions	(Science group, 2018)
4.3 Don't check that chicken fried in the pan or oven is heated on all surfaces or that minced chicken meat is cooked to the core	4.3 Make sure that all surfaces are exposed to heat and the minced meat products are heated to sufficient core time/temperature	S, C	70% of consumers (10 European countries) do not check if chicken is cooked on the surface and 50% does not check the core.	Langsrud et al. (2020)
4.4 Eating undercooked/raw molluscs	4.4 Mix well and cook bivalve molluscs such as mussels and clams 3–5 minutes after opening	N	1% of consumers prefer bivalve molluscs not thoroughly cooked	Scholderer (2022)
5. Storing				
5.1 Don't control the fridge temperature	5.1 Check temperature that the temperature in the part of the fridge where RTE is kept at 4C or below	L	21% of consumers (10 European countries) don't know the temperature of their fridge (SC). 80% of consumers have a median temperature above 4 °C	(Dumitraşcu et al., 2020; Scholderer, 2022)
5.2 Temperature abuse during storage: keep certain RTEs such as cold smoked fish, cold meat, cut fruit or soft cheeses at room temperature	5.2 Keep all RTE foods in refrigerator and never >2 hours outside fridge	L, S	0–1% keep high risk foods in the kitchen (a shelf, counter or cupboard). 8% keep cold meats or soft cheese outside the refrigerator for more than 2 hours, and 10% keep cut fruit outside the fridge for over 2 hours	Scholderer (2022)
6. Serving/eating				
6.1 Eat food after due-by date	6.1a Only buy RTE that you will be able to eat before the due-by-date, never eat RTE that has expired 6.1b Heat food that has been expired	L	Percentage of consumers (10 European countries) not checking due by date at home: 45% for cold meat, 75% for cold smoked fish, 86% for soft cheese, 49% for eggs and 84% cut fruit.	Scholderer (2022)
6.2 Prepare food for others in the household when sick	6.2a Not handle/cook/serve food for others when sick for at least two days after being sick. Leave food handling to others (children or spouse) 6.2b Cook readymade (self-serving) meals (pizza, frozen lasagne, breakfast cereals) and foods not needed to be handled by hands. 6.2c Strict hygiene when someone in the household is sick: Washing hands with soap	N, S	No data	

(continued on next page)

Table 1 (continued)

Target practice	Safer practice	Pathogen	Frequency target practice	Reference
	properly before handling/serving food and after being to the bathroom. Don't share towels. Keep distance. Separate bathroom if possible. Clean&Disinfect surfaces regularly Separate glasses/forks etc			

or a language that initiates fear, disgust, or social pressure, have been found to be effective communication tools (Olsen, Rossvoll, Langsrud, & Scholderer, 2014; Scholderer & Veflen, 2019; Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007; Slovic, Fischhoff, & Lichtenstein, 1980; Veflen, Scholderer, & Langsrud, 2020) but may be questionable from an ethical point of view (Lupton, 2015). In final communication materials information about the risk itself as well as graphics supporting the message should be included.

4. SafeConsume roadmap for food safety messages

SafeConsume was a Research&Innovation Action supported by the European Commission aiming to develop scientifically proven communication, education and policy strategies as well as tools and products that can help consumers mitigate the risk of food borne infection. The 66 month project, running from 2017 to 2022, had a budget of 9.5 mill Euro and 32 partners covering 14 European countries (Belgium, Denmark, France, Germany, Greece, Hungary, Norway, Portugal, Romania, Spain, Sweden, Switzerland, Turkey, and UK) including people from academia, industry, governmental and non-governmental organisations. The project results were based on a *trans*-disciplinary approach where experts from different disciplines merged methodologies and worked together to collect and understand data. Examples of outcomes are educational materials for teenagers in five languages, a food safety game in nine languages, four product prototypes, a risk communication self-evaluation tool for food authorities and 53 scientific papers backing up the risk mitigation strategies (Langsrud, 2022).

4.1. Expert panels

Over twelve workshops (October 16th' 2020–March 17th' 2021), an expert panel of the eight Steering board members of SafeConsume covering different European regions (Hungary, Norway, Portugal, Romania, Switzerland, UK) and disciplines (food microbiology, consumer science, marketing, sociology, risk analysis, innovation, policy, education) developed a list of food safety messages with a high-risk reducing effect if implemented among consumers. The potential ease of uptake of the messages was assessed by a broader expert panel consisting of SafeConsume partners (N = 48), including people from academia (sociology, microbiology, risk communication, innovation, education), governmental and non-governmental institutions (health, food, education) and industry (consumer goods) in a web-based survey. In a first round (September 2021), all practices suggested by the Steering board were included. In a second round (April–May 2022), the practices scoring highest on opportunity were included together with corresponding messages from WHO “Five keys to Safer food”.

4.2. Development of food safety messages

Fig. 1 shows the steps conducted to develop the food safety messages with sources, theoretical framework, data collection and analysis methodology. The initial list of food safety messages was based on potential risk reduction, taking into account the most significant food pathogens (see Section 2 and Table 1) and corresponding foods often implicated in outbreaks or in sporadic cases (eggs, chicken meat, bivalve molluscs ready-to-eat and ready-to-cook foods) as well as the role of sick food handlers (European Food Safety Authority & European Centre for

Disease Prevention and Control, 2021; World Health Organisation, 2015). Original data from the SafeConsume project, consumer practices and associated beliefs, knowledge and material environment, effects on hazards and risk reduction, HACCP analysis as well as literature reviews on these topics were collected and summed up. For each Pathogen-Food combination, observed and self-reported practices were considered. Common unsafe practices where a change could lead to at least 100 000-fold reduction in frequency or number of bacteria/virus were selected (Table 1). In the SafeConsume fieldwork, Theory of practice (Shove, Pantzar, & Watson, 2012) and Theoretical domains framework (Michie et al., 2011) were used to understand consumer practices (Eley et al., 2022; Skuland et al., 2020; Syeda et al., 2021). Food safety messages were formulated from the final list of “unsafe” and corresponding “safe” practices. State of the art principles for risk communication were followed aiming to propose emotionally neutral and easy to understand fact-based advice as explained in Section 3. For considering the ease of uptake of food safety messages, a methodology for developing and evaluating interventions to change behaviour, the behaviour change wheel was used (Michie et al., 2011).

4.3. Evaluation of food safety messages

A web-based survey was used where respondents considered food safety messages based on four criteria on an 1–5 Likert scale.

- Understanding: You will now be presented 26 different food safety advice. Please, read them carefully and evaluate how easy they are to understand
- Capability: How capable do you think a typical consumer from your home country would be to follow the different food safety advice? A capability is defined as the individual's psychological and physical capacity to engage in the activity concerned. Please, consider necessary knowledge and skills when answering the questions.
- Motivation: How motivated do you think a typical consumer from your home country would be to follow these different advice? Motivation is defined as all those brain processes that energize and direct behavior, not just goals and conscious decision-making. It includes habitual processes, emotional responding, as well as analytical decision-making. Think about habits, routines and willingness to comply when answering these question
- Opportunity: Does a typical consumer in your home country have the opportunity to follow these food safety advice? Opportunity is defined as all the factors that lie outside the individual that make the behavior possible. Think about both social and physical opportunities or barriers when evaluating the ease of complying to the statements below.
- Total score: The product of scores for Capability, Motivation and Opportunity

The scores are given in Table 2. For each potential change of practice, the capability, motivation, and opportunity for consumers to change was discussed and summed up. Finally, the results from the surveys were discussed by the whole consortium and some messages were improved based on identified barriers for implementation.

5. Food safety messages with potential high uptake among consumers

Table 3 shows the final proposed food safety messages for consumers together with corresponding messages from the WHO - “Five Keys to Safer Food” and the common safe and unsafe kitchen practices linked to the messages. In the discussion below giving the background for the final food safety messages, the final food safety messages are given in bold letters.

5.1. *Campylobacter* and *Salmonella* in raw chicken

Campylobacter was the most common pathogen causing food borne infections in Europe in 2021 followed by *Salmonella* (European Food Safety Authority & European Centre for Disease Prevention and Control, 2022). Both pathogens are associated with raw poultry and ingestion can occur directly through consumption of undercooked chicken or transfer of pathogens from raw chicken to hands or other foods during preparation. Pathogens occur at highest numbers on the surface of the meat but may also be found in the core (Luber & Bartelt, 2007). Still, 70% of consumers report that they do not check if chicken meat is cooked on the surface and 50% do not check the core (Langsrud et al., 2020). Consumer practices that may lead to cross-contamination are also common. Less than 50% of the European consumers wash hands with soap after touching chicken, even when observed (Didier et al., 2021; Kasza, Csenki, Izso, & Scholderer, 2022). In some countries using cutting boards and knives for vegetables without cleaning after chicken cutting is the most common practice observed. In these countries the consumers do not mention pathogens associated with chicken (Moretto et al., 2021).

Based on this, the following unsafe practices were suggested as targets for food safety messages: 1) Hands, knives, fork, cutting boards or sink are in contact with raw chicken and then with mouth or Ready-to-eat (RTE) food, and 2) Not checking that chicken fried in the pan or baked in the oven is heated on all surfaces or that minced chicken meat is cooked to the core.

As observed in the field work (Skuland et al., 2020), consumers may use a number of different strategies that reduce cross contamination (sometimes not intentionally), such as not touching the raw meat, buying products that does not need to be handled or preparing salad before chicken. At the same time, washing practices were often

insufficient (short rinse or wiping hands with a dirty cloth). Among different messages in the expert survey, “Use a clean knife and cutting board when cutting fruit and vegetables for consumption”, “Separate raw chicken from ready-to-eat foods, such as cooked chicken, salad vegetables and bread” and “Wash your hands before handling food and often during food preparation” (WHO) got the highest scores and were considered to cover cross-contamination issues. Based on discussions in the expert panels, the following messages were suggested “Use a clean knife and cutting board when cutting fruit and vegetables to be eaten raw”, “Separate raw meats from other foods during storage and food preparation” and “Always wash hands with soap after handling raw foods”.

For the top scored cooking message, “Check that chicken fried in the pan or baked in the oven is heated on all surfaces and that minced chicken meat is cooked to the core”, the score on understanding (3.9) and capability were relatively low. Barriers identified for changing practice were that it is difficult to monitor thoroughness both using the appearance or a food thermometer, that rapid and accurate thermometers are expensive, and preferences for juicy meat. Also, it was questioned if consumers would understand the term “core” and suggested to use “centre”. The alternative from WHO “For meat and poultry, make sure that juices are clear, not pink. Ideally, use a thermometer” got a high score on understanding but a low total score, probably for the same reasons as the message suggested by the expert group. The most important issue was though, whether the WHO recommendation is scientifically sound from a safety standing point. After WHO recommendations were made, it has been shown that poultry meat changes the colour from pink to white below 70 °C (Langsrud et al., 2020). Also, red meat packaged in high oxygen packaging change the colour at unsafe temperatures because of premature browning (Røssvoll et al., 2014). It should therefore be considered to remove the advice about the colour of juices. Another cooking advice from WHO uses the terminology “cook thoroughly” which and received a low score on understanding (3.9), because there is a large variety in how consumers perceive when food is sufficiently cooked to be safe (Langsrud et al., 2020). The final food safety messages on cooking were: “Cook pan-fried chicken on all sides” and “Check that minced meat products (meat balls, hamburgers) are cooked to the centre (70 °C)”

During the discussions, the expert groups were very unsure about the actual effect of asking people to wash their hands after touching raw chicken: Many people already know that they should wash their hands,

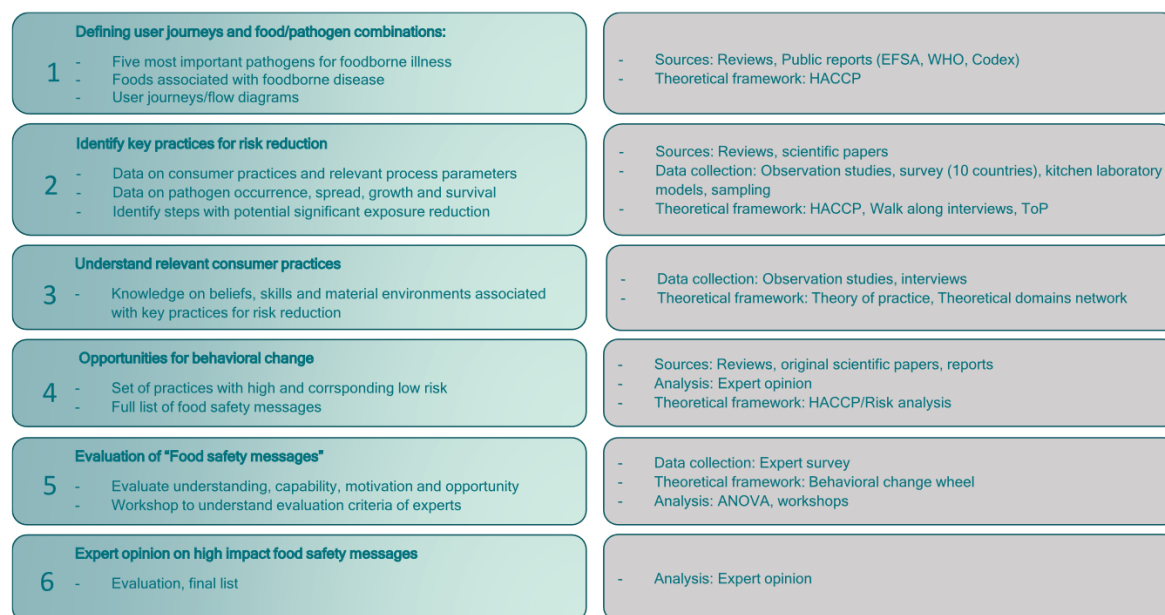


Fig. 1. Process and sources for developing Key Food Safety Messages.

Table 2

Food safety messages scores of understanding, capability, motivation and opportunity for changing behaviour. Questions with different letters within a row are significantly different. Mean values of 38 responses and standard deviations are given.

	Understanding ^a	Capability ^b	Motivation ^c	Opportunity ^d	C*M*O ^e
Handling food					
A2 Use clean knife and cutting board when cutting fruit and vegetables for consumption	4.7 (0.7)	4.1 (1.0)	3.8 (1.1)	4.4 (0.8)	73.4 (36.5)
A8 Separate raw chicken from ready-to-eat foods, such as cooked chicken, salad vegetables and bread	4.4 (0.7)	4.1 (1)	3.7 (1.1)	4.3 (0.8)	69.0 (36.3)
A19 Wash your hands before handling food and often during food preparation	4.2 (1.0)	4.0 (1.2)	3.7 (1.0)	4.5 (0.7)	68.9 (31.5)
A4 Avoid hand contact with mouth or ready-to-eat foods (e.g. bread, leafy greens) when handling raw chicken	4.3 (0.8)	3.9 (1.0)	3.8 (1.0)	4.5 (0.7)	68.4 (33.7)
A22 Separate raw meat, poultry and seafood from other foods	4.3 (0.8)	4.0 (0.9)	3.6 (1.1)	4.2 (1.0)	66.3 (37.6)
A23 Use separate equipment and utensils such as knives and cutting boards for handling raw foods	3.9 (1.0)	3.7 (1.0)	3.4 (1.2)	4.1 (1.0)	54.6 (36.0)
A21 Wash and sanitize all surfaces and equipment used for food preparation	3.9 (1.1)	3.4 (1.3)	3.3 (1.1)	4.2 (0.9)	52.3 (34.3)
A11 Prepare salad before chicken	4.1 (1.2)	3.7 (1.5)	2.7 (1.3)	4.5 (0.9)	50.2 (36.8)
A14 Buy chicken products that need no handling and are right for the recipe, e.g. ready cut chicken breast for a stew	4.2 (0.9)	3.4 (1.1)	2.8 (1.2)	4.0 (1.1)	45.2 (34.4)
Cooking food					
A9 Check that chicken fried in the pan or oven is heated on all surfaces and that minced chicken meat is cooked to the core	3.9 (1.1)	3.6 (1.2)	3.9 (1.0)	4.3 (1.0)	69.4 (40.0)
A24 Cook food thoroughly, especially meat, poultry, eggs and seafood	3.9 (1.0)	3.9 (0.7)	3.5 (1.0)	4.6 (0.6)	64.7 (28.8)
A7 Cook ready-to-heat foods (e.g. frozen fruit/berries/vegetables, dinner sausages and hamburgers) according to label	4.1 (1.1)	4.0 (0.9)	3.4 (0.8)	4.4 (0.8)	62.4 (30.4)
A10 Heat foods that have been in contact with raw chicken or chicken juices	3.7 (1.0)	3.6 (1.0)	3.5 (1.1)	4.4 (0.9)	60.7 (36.8)
A13 Mix well and cook clams and mussels 3–5 min after shells are open	3.9 (1.0)	3.5 (1.4)	3.3 (1.2)	4.3 (1.1)	57.3 (38.7)
A26 Bring foods like soups and stews to boiling to make sure that they have reached 70 °C. For meat and poultry, make sure that juices are clear, not pink. Ideally, use a thermometer	4.6 (0.7)	3.7 (1.3)	3.1 (1.0)	4.4 (0.7)	52.7 (31.8)
A12 Don't eat undercooked eggs or dishes with raw eggs from backyard hens or other uncontrolled sources	3.9 (1.0)	3.5 (1.2)	2.7 (1.1)	4.2 (1.1)	42.2 (31.3)
Storage and due by dates					
A1 Store ready-to-eat foods, such as cold smoked fish, cold meat, cut fruit, soft cheeses, or raw egg dishes in the refrigerator	4.7 (0.5)	4.5 (0.8)	4.2 (1)	4.5 (0.8)	88.4 (34.2)
A3 Purchase and eat ready-to-eat food (e.g. cold smoked fish, cooked meat, cut fruit, soft cheeses, or raw egg dishes) before the due-by-date	4.6 (0.7)	4.1 (0.8)	4 (0.9)	4.5 (0.7)	75.9 (30.7)
A32 Do not use food beyond its expiry date	4.7 (0.6)	4.1 (0.9)	3.6 (0.9)	4.3 (0.8)	67.1 (29.1)
A27 Refrigerate promptly all cooked and perishable food (preferably below 5 °C)	3.8 (1.1)	3.6 (1.0)	3.4 (1.0)	4.1 (0.9)	51.9 (26.8)
A28 Do not store food too long even in the refrigerator	3.3 (1.4)	3.4 (1.1)	3.3 (1.0)	4.3 (1.0)	51.3 (28.9)
A25 Do not leave cooked food at room temperature for more than 2 hours	3.5 (1.1)	3.3 (1.2)	3.3 (1.0)	3.9 (1.2)	47.8 (32.6)
A15 Make sure that foods are kept cool during transport from shop or are cooled within 2 h from purchase	4.2 (0.9)	3.4 (1.0)	3.2 (1.0)	3.7 (0.9)	44.6 (30.2)
A5 Control the fridge temperature (between 0 and 4 °C)	4.4 (0.9)	3.3 (1.1)	3.0 (0.9)	3.5 (1.0)	37.9 (27.9)
A30 Choose foods processed for safety, such as pasteurised milk	3.7 (1.1)	3.6 (1.3)	3.1 (1.2)	4.4 (0.7)	56.2 (37.8)
A29 Select fresh and wholesome food	3.3 (1.3)	3.2 (1.0)	3.9 (0.9)	3.8 (0.9)	49.7 (27.1)
A16 Select product with preservatives when possible (e.g. sliced ham, sausages)	3.6 (1.2)	3.1 (1.2)	2.3 (1.0)	4.4 (0.9)	36.1 (28.3)
Rinsing fruit and vegetables					
A31 Wash fruits and vegetables, especially if eaten raw	4.8 (0.5)	4.3 (0.9)	3.8 (0.9)	4.7 (0.5)	78.5 (32.0)
A6 Rinse fresh produce, fruit and vegetables thoroughly in water before eating, even those with peel	4.5 (0.8)	4.1 (1.1)	3.4 (1.0)	4.6 (0.6)	67.1 (31.9)
Personal hygiene					
A20 Wash your hands after going to the toilet	4.9 (0.4)	4.5 (0.9)	4.3 (0.7)	4.8 (0.5)	91.6 (28.3)
A18 Keep distance and focus on improving the hygiene practices if one in the family is sick	3.7 (1.3)	3.2 (1.2)	3.2 (1.0)	3.5 (1.2)	40.9 (31.9)
A17 When someone is sick: cook ready made meals (pizza, frozen lasagne, breakfast cereals) and foods not needed to be handled by hands	3.5 (1.3)	3.5 (1.2)	2.7 (1.3)	3.9 (1.1)	39.9 (30.7)

^a Understanding: You will now be presented 32 different food safety messages. Please, read them carefully and evaluate how easy they are to understand.

^b Capability: How capable do you think a typical consumer would be to follow the different food safety advice? A capability is defined as the individual's psychological and physical capacity to engage in the activity concerned. Please, consider necessary knowledge and skills when answering the questions.

^c Motivation: How motivated do you think a typical consumer from your home country would be to follow these different advice? Motivation is defined as all those brain processes that energize and direct behavior, not just goals and conscious decision-making. It includes habitual processes, emotional responding, as well as analytical decision-making. Think about habits, routines and willingness to comply when answering these question.

^d Opportunity: Does a typical consumer in your home country have the opportunity to follow these food safety advice? Opportunity is defined as all the factors that lie outside the individual that make the behavior possible. Think about both social and physical opportunities or barriers when evaluating the ease of complying to the statements below.

^e C*M*O: Product of Capability, Motivation and Opportunity.

and it was obvious from the field work and the literature that this practice is highly habitual and unconscious and therefore difficult to change through information alone. It was agreed that education at a young age may be a more efficient alternative than informing adults. Also, to be able to comply with the advice on food thermometers, there is a need for more convenient and cheap products for consumers.

5.2. *Salmonella* in eggs

Salmonella was the second most common reported pathogen causing food borne infections in Europe in 2021, and eggs and egg products the most common vehicle for *Salmonella* in outbreaks (European Food Safety Authority & European Centre for Disease Prevention and Control, 2022). The main effort in EU to reduce incidents, and which has resulted in a decline in cases, has been to reduce the incidence in laying hens, while consumers have been encouraged to practice “safe handling of raw meat and other raw food ingredients” (European Food Safety Authority, 2022). Thorough heat treatment can kill *Salmonella*, but eggs are commonly eaten raw or partly raw (whole eggs with running yolk) or used raw in many dishes (e.g., tiramisu). Persuading people to totally stop eating common, traditional dishes through food safety messages was not considered to be feasible and was ruled out early in the discussions in the expert group. Also, making people store whole eggs in the refrigerator was also ruled out on the basis that eggs are often kept at room temperature in shops and may not be labelled as foods to be kept cool.

In the SafeConsume survey covering 10 European countries, it was shown that 13% of Europeans typically get uncontrolled eggs from a backyard (Scholderer, 2022). In a follow up investigation, we found that such uncontrolled eggs may have significantly higher incidence of *Salmonella* than industrially produced eggs (Cardoso et al., 2021; Ferreira et al., 2020). Reducing consumption of such eggs, especially raw or undercooked, could therefore contribute significantly to reducing exposure to *Salmonella*. Considering eggs that are contaminated on the surface with possible contamination of the egg mass during preparation, keeping dishes made of raw eggs at temperatures not allowing growth of *Salmonella* could potentially reduce the exposure to infectious doses (Cardoso et al., 2021).

Based on these considerations, common, unsafe consumer practices that were targeted for food safety messages were 1) The use of backyard eggs for dishes that will not be fully cooked, and 2) Keep dishes with raw eggs at temperatures allowing growth of *Salmonella*.

The food safety message “Don’t eat undercooked eggs or dishes with raw eggs from backyard hens or other uncontrolled sources” got a relatively low total score (42.2). Also, in the initial survey, both the message “Before consumption, cook thoroughly eggs that may contain *Salmonella*” and “Choose *Salmonella* free eggs for dishes that are not cooked” got low scores. Several barriers were identified that would prevent people from changing to industrially produced eggs, even for undercooked egg dishes, such as preferences (home-made food, natural foods), convenience (distance to supermarkets in some areas), ethics (animal welfare) and price, but most importantly the lack of access to *Salmonella* free eggs in many markets. The WHO five keys mention eggs specifically in connection with cooking. However, as discussed above, it was not considered a realistic scenario to convince European consumers to stop eating common dishes with raw or undercooked eggs.

Regarding storing conditions, “Store ready-to-eat foods such as cold smoked fish, cooked meat, cut fruit, soft cheese, and raw egg

dishes in the refrigerator (below 5 °C)” got a high score for uptake (88.4) and understanding (4.7) and no specific barriers regarding eggs were listed in the workshop. The WHO five keys mention eggs specifically in connection with cooking, but not cooling. It was concluded that including cool storage of egg dishes among the food safety messages can reduce risk of foodborne infection and that the potential uptake of this is high.

Information campaigns towards people with backyard eggs focusing both on cold storage of eggs and hygiene was discussed but considered to be outside the scope. It was concluded that to reduce infections from *Salmonella* in eggs, policy actions such as cool chain management regulations for eggs and information on egg storage for small scale farmers and households with backyard eggs should be initiated. This may have a more significant effect than food safety messages. Also, better access to *Salmonella* free eggs and egg products, as well as devices and instructions for home pasteurisation could mitigate the risk.

5.3. *Listeria monocytogenes* in ready-to-eat (RTE) food

Listeria monocytogenes is the pathogen causing most foodborne deaths in Europe (European Food Safety Authority & European Centre for Disease Prevention and Control, 2022). It is associated with foods that support the growth of the pathogen but are intended to be eaten without cooking (e.g., packaged heat-treated meat products, cold smoked fish, and soft cheeses). An increasing tendency of outbreaks linked to fruit and vegetables has been reported (European Food Safety Authority & European Centre for Disease Prevention and Control, 2021; Zhu, Goo-neratne, & Hussain, 2017). About one third of the listeriosis cases are caused by growth of *Listeria* in the consumer phase, both reflecting consumer practices and the state of refrigerators (EFSA BIOHAZ Panel (EFSA Panel on Biological Hazards) et al., 2018). Both monitoring in the SafeConsume project and other projects have shown that domestic refrigerators are often kept at temperatures that are too high (Dumitracu et al., 2020; James, Onarinde, & James, 2017). Also, large fractions in the consumers in a survey from ten European countries report that they do not check the due-by-date of high-risk foods (Scholderer, 2022).

As for *Salmonella* and eggs, it was regarded too difficult to stop people from eating foods associated with *L. monocytogenes*, maybe with the exception of people in certain high-risk groups such as pregnant women and those being aware that they are immuno-compromised. For others, the main practices to be targeted for food safety messages were 1) Keep RTE food above 4 °C and eat after due-by- date, 2) Buy RTE food that support pathogen growth when an alternative with preservatives is available. 3) Don’t cook foods according to label (e.g., frozen fruit/berries/vegetables, sausages, dinner dishes).

A high score for uptake were found for “Store ready-to-eat foods such as cold smoked fish, cooked meat, cut fruit, soft cheeses, or raw egg dishes in the refrigerator (below 5°C)”. Still barriers for adopting this practice were identified. For example, several foods associated with *Listeria* are not associated with risk, either because they are not easily spoiled (soft cheese) or they are considered healthy (fruits and vegetables). Some foods may also taste better at higher temperatures (e.g., soft cheese) and they are served typically on buffets. Also, limited space in the fridges, e.g., for students sharing the same refrigerator or in large families may result in storage of foods outside the refrigerator. Another message also getting high scores was “Purchase and eat ready-to-eat foods such as cold smoked fish, cooked meat, cut fruit, soft cheeses, or raw egg dishes before the due-by-date”. A

lot of barriers for change were mentioned during the discussions, such as unwillingness to waste food for ethical or economic reasons, low frequency shopping and not checking the date label. Low scores were obtained for messages on controlling that the temperature is below 5 °C. Here, hypersensitivity to cold foods, efforts to measure and calibrate thermometers and habits were mentioned as barriers. Also, as observed in the fieldwork in the project, beliefs that it is possible to sense the temperature, that consumers do not understand the scale of the button, lack of thermometers and turning off the refrigerator to save electricity were mentioned (Borda et al., 2020; Skuland et al., 2020). The corresponding food safety messages from WHO on cool storage and expiry dates (Table 3) got lower scores and it was commented that they were too vague about high-risk foods, time, and temperature.

Low scores were obtained for buying products with preservatives,

something that was explained by the fact that, in many countries, consumers believe that preservatives are not healthy and associate them with low quality foods. WHO gives advice about buying foods “processed for safety” which the expert group considered too difficult for consumers to understand.

Some barriers for adopting the message “Cook ready-to-heat foods (e.g., frozen fruit/berries/vegetables, dinner sausages and hamburgers) according to label were preferences, convenience and perception of cooked foods as being safe and ready to eat. The message was changed slightly to be clearer: “Cook ready-to-heat foods (e.g., dinner sausages and hamburgers) and frozen fruit/berries/vegetables according to label”

A weakness with the suggested messages were that they are quite long, a result of that many consumers are not aware of all types of high-

Table 3

Existing unsafe consumer practices and corresponding safe practices, existing messages (WHO) and final food safety messages suggested by SafeConsume.

Area	Existing unsafe practice	Safe practice(s)	WHO message	Suggested message(s)*
Handling food: <i>Salmonella</i> & <i>Campylobacter</i> on raw chicken	Hands/knives/fork/cutting boards/sink in contact with raw chicken and then with mouth or RTE food	Hands: Wash hands with soap and water after touching raw chicken Kitchen utensils: Wash with soap and water and dry before using for RTE Distance in time and space between RTE and raw chicken. Buy chicken products that need no handling Prepare salad before chicken Heat foods that have been in contact with chicken or chicken juices	<ul style="list-style-type: none"> Use separate equipment and utensils such as knives and cutting boards for handling raw foods Wash and sanitize all surfaces and equipment used for food preparation Wash your hands before handling food and often during food preparation Separate raw meat, poultry and seafood from other foods 	<ol style="list-style-type: none"> Use a clean knife and cutting board when cutting fruit and vegetables to be eaten raw Separate raw meats from other foods during storage and food preparation Always wash hands with soap after handling raw foods
Cooking: <i>Salmonella</i> & <i>Campylobacter</i> on raw chicken Norovirus & <i>Salmonella</i> from bivalve molluscs Norovirus, <i>Listeria</i> & <i>Salmonella</i> in Ready-to-heat foods	Not check/perform a process to make sure that chicken surfaces, minced meat or bivalve mussels are cooked sufficiently Not cook frozen fruit/berries/vegetables, or dinner sausages	Make sure that chicken is thoroughly cooked: All surfaces heated (colour, cooking in sauce) and core cooked (thermometer) Mix well and cook bivalve molluscs such as mussels and clams 3–5 minutes after opening Heat food according to label	<ul style="list-style-type: none"> Bring foods like soups and stews to boiling to make sure that they have reached 70 °C. For meat and poultry, make sure that juices are clear, not pink. Ideally, use a thermometer Cook food thoroughly, especially meat, poultry, eggs and seafood 	<ol style="list-style-type: none"> Cook pan-fried chicken on all sides Check that minced meat products (meat balls, hamburgers) are cooked to the centre (70 °C) Cook ready-to-heat foods (e.g., dinner sausages and hamburgers) and frozen fruit/berries/vegetables according to label
Storage, due-by date: <i>Listeria</i> in Ready-to-eat foods and <i>Salmonella</i> in eggs	Keep RTE food above 4 °C and eat after due-by date Buy RTE food that support pathogen growth. Keep raw eggs and dishes with raw eggs at temperatures allowing growth of <i>Salmonella</i>	Check that the temperature in the part of the fridge where RTE is kept keeps below 5 °C Keep all RTE foods in refrigerator and never >2 hours outside fridge Never eat RTE that has expired Heat food that has been expired Select foods with preservatives	<ul style="list-style-type: none"> Refrigerate promptly all cooked and perishable food (preferably below 5 °C) Do not leave cooked food at room temperature for more than 2 hours Do not use food beyond its expiry date Do not store food too long even in the refrigerator Select fresh and wholesome food Cook food thoroughly, especially meat, poultry, eggs and seafood 	<ol style="list-style-type: none"> Store ready-to-eat foods such as cold smoked fish, cooked meat, cut fruit, soft cheese, and raw egg dishes in the refrigerator (below 5 °C). Purchase and eat ready-to-eat foods such as cold smoked fish, cooked meat, cut fruit, soft cheeses, or raw egg dishes before the due-by-date
Rinsing: <i>Toxoplasma</i> , norovirus, <i>Listeria</i> & <i>Salmonella</i> on fresh produce	Do not wash fruit and vegetables	Decontaminate fresh produce with a sanitizer or rinse and rub in water for at least 15 sec	<ul style="list-style-type: none"> Wash fruits and vegetables, especially if eaten raw 	<ol style="list-style-type: none"> Wash fruits and vegetables to be eaten raw, even those with a peel
Personal hygiene: Pathogens (Norovirus, <i>Salmonella</i>) from infected food handler	Preparing foods for others when being sick	Not handle/cook/serve food for others when sick for at least two days after being sick. Keep distance and improve hygiene Cook foods not needed to be handled when someone is sick	<ul style="list-style-type: none"> Wash your hands after going to the toilet 	

risk foods. Graphics could potentially replace some of the text. Policy and kitchen appliances producers' actions are also needed to aid consumers, e.g., regulations and technologies to make sure that refrigerators keep stable and sufficiently low temperature. Also, information campaigns about the safety of preservatives should be initiated. Finally, cooking instructions on "Ready-to-cook" foods should tell consumers that the instructions are linked to safety.

5.4. Norovirus from bivalve molluscs

Norovirus is estimated to cause 15 million cases in Europe every year and one out of three of the cases are linked to contaminated bivalve molluscs. Since norovirus is also effectively spread from person to person, a foodborne infection is often followed by secondary infections, and the proportion of cases that are foodborne is estimated to be 17% (Guix, Pinto, & Bosch, 2019). Oysters are commonly involved in outbreaks, but to stop people from eating oysters through information was not considered realistic. To reduce risk, clams and mussels should be thoroughly cooked, and a performance criteria of 3.5 log reduction has been suggested (Fuentes et al., 2021). A common rule of thumb has been to cook mussels and clams for at least for 90 seconds at 90 °C (Guix et al., 2019). Recent research has indicated that an exposure time of at least 5 minutes in boiling water may be necessary for an effective reduction of risk. For steaming molluscs, a total time of 14 minutes at 90 °C (after shells has opened) would be necessary (Guix et al., 2019). However, according to the SafeConsume survey, these practices are rare: 13% of European consumers cook clams and mussels until they are open and only 8% cooked more than 2 minutes after they have opened. 3% of consumers claim that they use a thermometer while 1% prefer clams and mussels not thoroughly cooked (Scholderer, 2022).

Based on this, the practice targeted for food safety messages was: Clams and mussels not cooked at sufficient time and/or at a sufficient temperature.

The food safety message "Mix well and cook clams and mussels 3–5 min after shells are open" got a low score. Important barriers were that people prefer juicy molluscs, the advice is not in line with cooking books and that many consumers have low skills. The corresponding message from WHO (Cook food thoroughly, especially meat, poultry, eggs, and seafood) was not considered as being able to inform people effectively about how to cook bivalve molluscs. In conclusion, it seems difficult to make consumers cook this type of food safely, and efforts should be done earlier in the chain to reduce exposure to norovirus from bivalve molluscs.

5.5. Toxoplasma, Salmonella, Listeria and norovirus on fresh produce

Fresh produce has received increased attention from causing outbreaks in recent years, and a wide variety of pathogens have been implicated (Ajedun, Onarinde, Swainson, & Dixon, 2021; Zhu et al., 2017). Also, fruits with a peel, such as melons, have been involved in outbreaks indicating that people are not aware that also these fruits should be washed.

To effectively reduce pathogens such as norovirus from fresh produce, consumers need to use a biocide (Anfruns-Estrada, Bottaro, Pinto, Guix, & Bosch, 2019)), but only 3% of consumers report that they use bleach and 3% a disinfectant for vegetables when rinsing. 17% of consumers claim that they rinse under running water with scrubbing for at least 30 sec and 26% until soil is removed. (Scholderer, 2022). It was considered that using disinfectants for rinsing is controversial in many countries and safe biocidal consumer products for rinsing fresh produce are missing in many markets. Also, many consumers would not have the skills to make proper dilutions of disinfectant concentrates for rinsing. The present advice from WHO "Wash fruits and vegetables, especially if eaten raw" got the highest score while the alternative message got a lower, (but still high) score "Rinse fresh produce, fruit and vegetables thoroughly in water before eating, even those with peel". It was decided

to combine the two messages including fruit with peel based on the outbreaks the last years: "**Wash fruit and vegetable to be eaten raw, even those with a peel**". To reduce the risk sufficiently, there is however a need for washing solutions for consumers that are cheap, safe and natural in all markets, overcoming the present low opportunity (not available), capacity (skills) and motivation (sound scepticism to biocides on food) that hinder safe practices.

5.6. Norovirus and other food pathogens from infected food handler

Several pathogens may spread from an infected food handler to food. Among these, norovirus stands out as extraordinary challenging with an infectious dose down to 1–10 virus particles and heavy shedding of the virus during and after infection (Bosch et al., 2018). A significant proportion of Norovirus cases are secondary infections spread by cross-contamination. Very strict hygiene would be necessary to prevent other family members from becoming infected, where thorough hand washing with soap and water is important but will still only reduce the number of virus particles by a factor of 10–1000. The target practice for behavioural change was therefore to: Prepare food for others when sick.

Ideally, to reduce risk, sick people should not prepare food for others, but this food safety message was excluded early as it was argued that many consumers, e.g., single parents, do not have this opportunity. Two alternative messages "When someone is sick: Cook readymade (self-serving) meals (pizza, frozen lasagne, breakfast cereals) and foods not needed to be handled by hands" and "Keep distance and focus on improving the hygiene practices if one in the family is sick" got very low scores. For choosing food with little handling, it was argued that certain traditions apply when someone is sick that prevent this practice. For example, caring for children through providing proper, home-made food may be a stronger force than avoiding cross-contamination. For hygiene, it was argued that this advice is difficult to implement, especially for families with little space. It was concluded that food safety messages aiming to prevent cross-contamination when someone in the family is sick would have low impact.

6. Food safety messages graphical abstract

The food safety messages were simplified and presented with graphics and the catchphrase "Tips to stay healthy" by a designer bureau (DesignIt) (Fig. 2). The bureau was also involved in the innovation activities in SafeConsume, including the transformation of research into tools, educational materials, communication strategies and policy recommendations.

7. Concluding remarks

An important challenge when giving advice on food safety is to cover the most important issues among the huge number of ways of eliminating or reducing the food associated hazards. We used the most common food-pathogen combinations associated with foodborne disease and health burden in Europe. However, it cannot be ignored that other foods and pathogens are also important and that significant underreporting occurs. Meanwhile, it should also be noted that the same practice, e.g., thorough cooking, will eradicate a number of different vegetative pathogens, not only those we target in this study. Although developed totally independently, the final list of proposed Food Safety Messages assessed for potential uptake, was roughly covering the same topics as in WHO's "Five keys for safer food" and the messages could therefore be compared. In general, the food safety messages proposed by the SafeConsume steering group got higher scores in the expert survey than those from WHO. Here, it is important to note that the WHO messages are targeting a global population, whereas the SafeConsume messages were considered from a European perspective. A reoccurring criticism of the WHO messages was that they are too vague to be able to initiate safe practices, something that may be unavoidable when



Fig. 2. Graphical presentation of Key Messages.

attempting to cover all people, foods and pathogens. Nevertheless, after 20 years, we suggest that WHO should reconsider the preventive risk communication based on new knowledge and new challenges. Also, it should be considered to make different communication materials and tools to different target groups or regions. In the US, the FightBac initiative (<https://www.fightbac.org>) has developed communication materials covering similar topics as the WHO and Safeconsume topics, but a direct comparison was not done. One should note that neither Safeconsume nor FightBac include advice on purchasing “safe food”. In case of Safeconsume, it was acknowledged that reducing consumption of high risk foods (e.g oysters, undercooked eggs, RTE without preservatives) would have a high impact of foodborne illness. Meanwhile, it was considered too difficult to change these practices through simple food safety messages and other strategies should be considered.

The present opinion suggests a wide and science-based approach to prioritise when evaluating potential food safety messages. This does not imply that the set of messages in this paper would fit for every purpose. Also, one could argue that consumers have the right to know about important risks and how to cope with them, even in cases where we expect a low general uptake. Occasionally, low-uptake practices can be circumvented by targeting other practices that compensate. For example, it may be difficult to stop people from eating undercooked backyard eggs, but some consumers with risk-aversion may consider pasteurising eggs before using them. Also, for those practices that are difficult to change, other measures to mitigate risk increases in importance, such as providing kitchen tools for safety (cheap and rapid food and fridge thermometers, shelf-life indicators, reliable refrigerators), gamification, supporting poor communities with running water, affordable power, and safe food, regulation of labelling and education of the young population.

Through this opinion we suggest an approach to prioritise between potential food safety messages by 1) using data from transdisciplinary science to map and rank consumer practices with regard to hazard reduction and to understand consumer behaviour and 2) use implementation science in an expert survey to analyse potential uptake. To fully evaluate the final set of food safety messages, a consumer test to see if the food safety messages can change behaviour would be necessary. Information about the risk and motivational material, as well as graphics should also be included. Also, one should have in mind that messages should take into consideration the target audience and the risk profile in the individual country. For preparing food safety advice at a global level, it is crucial to involve experts from all regions and with diverse expertise.

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Declaration of competing interest

None.

Data availability

The data is shared in supplementary material and in a data repository (link in references)

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