



## Self-reported practices by Portuguese consumers regarding eggs' safety: An analysis based on critical consumer handling points

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### ABSTRACT

In Europe, salmonellosis has been ranked as the second leading cause of hospitalization and death due to the consumption of contaminated food. Information about consumers' food safety perception, knowledge and practices in the domestic environment is lacking in order to define the main intervention opportunities to obtain a significant reduction in the occurrence of foodborne salmonellosis. We conducted an on-line survey of the Portuguese population on self-reported domestic egg handling and occurrence of illness from egg consumption, which were analysed in a Critical Consumer Handling (CCH) framework. Respondents (N = 927) reported behaviours associated with high risk of *Salmonella* infection, namely the frequent consumption of eggs from non-controlled sources (43%) and of dishes prepared with uncooked or lightly cooked eggs. Other risk related practices, from egg storage until consumption, were also found to be common. However, when buying eggs respondents value safety-related criteria above others – use-by date (highly valued by 72.8%), lack of cracks (72.2%) and cleanliness (48%). Association of eggs with *Salmonella* contamination was recognized by 65.8% of the respondents; 72.2% declared to have never been sick after eating eggs. In addition to global egg safety awareness messages, future campaigns should prioritize shifting consumers towards eggs with low probability of being contaminated and encouraging the use of pasteurized eggs, in particular when used in recipes that are not fully heat treated. The importance of storing backyard eggs at refrigeration temperature needs to be communicated.

### 1. Introduction

It is estimated that *Salmonella* spp. (non-typhoidal) cause about 153 million cases of salmonellosis and 57,000 deaths globally each year (Hunter & Watkins, 2017). In 2019, 8556 and 90,105 cases of salmonellosis were reported, respectively, in the US (Tack et al., 2020) and by 28 EU member states (EFSA & ECDC, 2021). Although source attribution of human salmonellosis is challenging (Pires, Vieira, Hald, & Cole, 2014), 'eggs and egg products' rank as the food vehicle with the most outbreak-associated cases – 9.3% of total cases in 2019 (EFSA & ECDC, 2021).

Private households have been identified as the most common place

of food consumption leading to salmonellosis outbreaks (EFSA & ECDC, 2021) and a place where contamination and mishandling of foods is frequent (Cardoso, Ferreira, Truninger, Maia, & Teixeira, 2021; Skuland et al., 2020; Evans & Redmond, 2019). Several studies focusing on consumers' food safety perception, knowledge and practices in the domestic environment have been conducted (Bremer et al., 2005; Henley, Stein, & Quinlan, 2012, 2015; Azevedo, Albano, Silva, & Teixeira, 2014; Thaivalappil, Young, Paco, Jeyapalan, & Papadopoulos, 2020; Tomaszewska, Trafialek, Suebpongsang, & Kolanowski, 2018), but research specifically toward eggs is scarce, particularly in Europe as most studies were conducted in the USA (reviewed by Cardoso, Nicolau, et al., 2021). There is a gap in knowledge about consumer egg handling practices in

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Portugal, a country where consumers are known to prize backyard eggs (Cardoso, Nicolau, et al., 2021; Ramos & Truninger, 2021) and *Salmonella* was detected on a significant share of backyard flocks (Ferreira et al., 2020). While many of previous studies highlight the need to improve awareness of food safety, they look over some of the challenges in promoting widespread change in food safety practices (Evans, 2011; Meah, 2014). Perceptions of food risk are influenced by institutional trust in the food distribution system (Ansell & Vogel, 2006; Halkier et al., 2007; Kjaernes, Havey, & Warde, 2007), and consumers often do not share the same priorities as experts when it comes to food safety – while experts highlight the importance of managing microbiological risk at home and along the food chain, consumers prioritize other food-related issues like food waste, pesticides and synthetic chemical residues on food (Truninger et al., 2019). Additionally, food consumption and hygiene practices are often shaped by cultural notions of propriety and entangled with the multitude of other domestic activities that comprise daily life (Meah & Watson, 2013; Meah, 2014; Rinkinen, Shove, & Smits, 2019; Wills, Dickinson, & Short, 2013; Wills, Meah, Dickinson, & Short, 2015). These day-to-day practices are often enacted out of habit without an overt reflection on the choices being made, influenced by shared cultural scripts and by the material elements of everyday life more than individual decision-making (Shove, 2010; Hargreaves, 2011; Warde, 2014). Drawing on the flow diagrams used in the food industry as the fourth step in implementing HACCP, a team of sociologists and food safety experts from six European countries (France, Hungary, Norway, Portugal, Romania, and UK) have previously developed a flowsheet describing all the steps, from purchase to consumption

of egg and egg-products, at household level (Hagtvedt et al., 2017). Those steps where consumers can, through actions or choices, significantly prevent, reduce or eliminate *Salmonella* were identified as Critical Consumer Handling (CCH) (Fig. 1) by analogy with the Critical Control Points (CCPs) in HACCP. These steps consist of egg acquisition (collection or purchase) (CCH1), handling before storage and preparation (CCH2), storage eggs/egg dishes (CCH3), cooking/preparation not involving heating (CCH4 and CCH5) and cooking leftovers (CCH6) (Cardoso, Nicolau, et al., 2021). This study aims to analyse food safety at home from the above framework combining a sociological approach with HACCP (Hazard Analysis Critical Control Point). We analyse self-reported practices related to egg handling at household level, with a particular focus on the critical handling points– from the time of acquisition until consumption.

## 2. Material and methods

The present paper uses a flow diagram from purchase to consumption earlier developed (Hagtvedt et al., 2017) as a framework for analysis of consumer Critical Consumer Handling (CCH) points of egg and egg-products at household level (Fig. 1). In this diagram, CCH1 is related to the choices consumers can make that can influence the likelihood of taking contaminated eggs into their homes (step 1), namely the preference for backyard eggs (either collected from own hens or given by respondents' social networks), the criteria for selecting eggs when buying and the criteria used to access the egg's safety. CCH2 refers to the hygiene practices when handling eggs both before storage (step 3) -

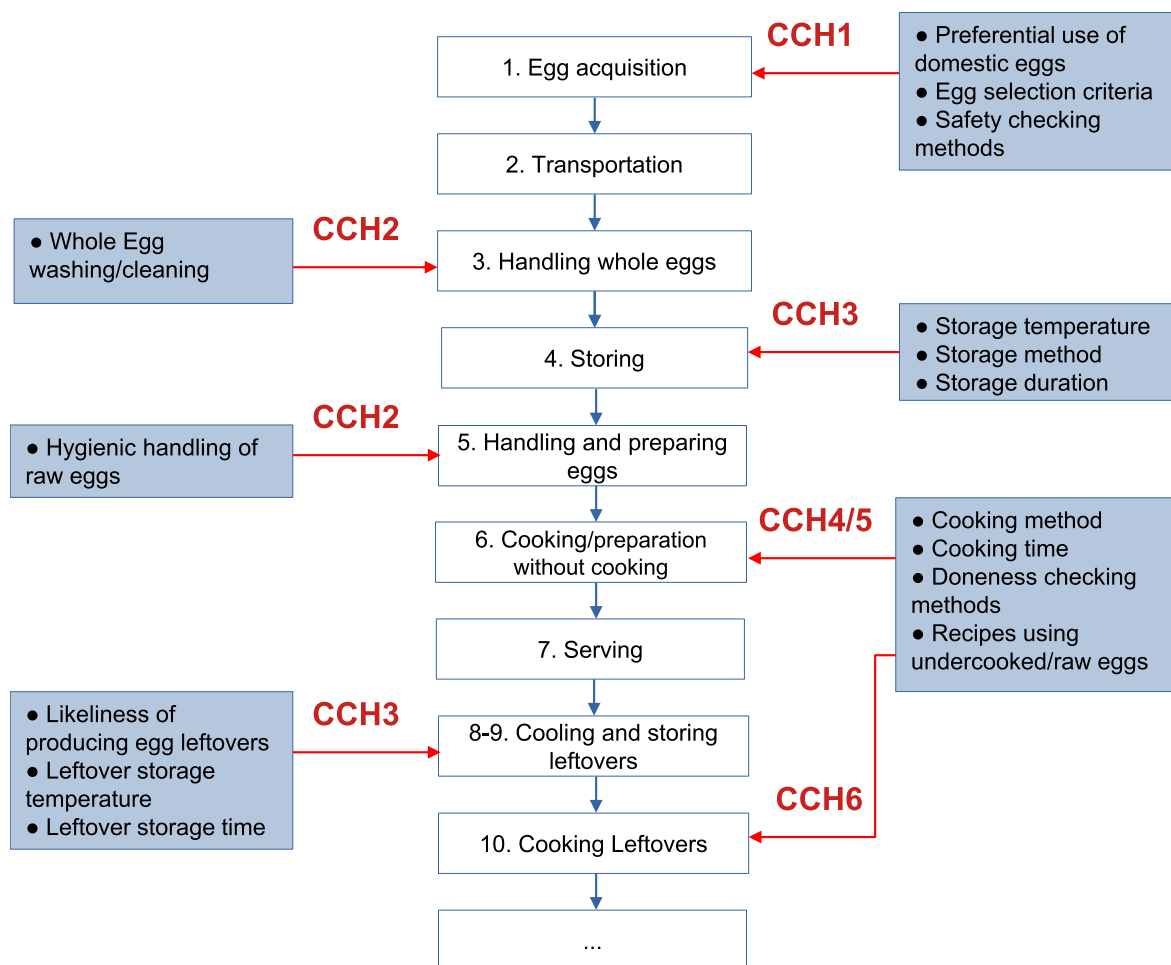


Fig. 1. Generic flowsheet for Critical Consumer Handling (CCH) of eggs/egg products (CCH - steps in the flow diagram show where consumers' actions or choices can reduce risk of salmonellosis significantly; flowchart developed in the frame of the SafeConsume project, based on work by Hagtvedt et al. (2017)).

washing or cleaning eggs - and before cooking or preparation (step 5) - washing and cleaning eggs; washing hands that come in contact with raw eggs during preparation and might lead to accidental ingestion of *Salmonella* by food handlers via the hand-to-mouth route. CCH3 is tied to egg storage, where consumers can reduce levels of *Salmonella* in contaminated eggs storing them at the appropriate temperature and consuming them timely before preparation (step 4) but also as leftovers (step 9). Finally, CCH4 and CCH5 refer to egg preparation practices (step 6), when consumers can opt to avoid recipes using raw or undercooked eggs or inactivate *Salmonella* with adequate cooking/preparation. CCH6 refers to step 10 where heating leftovers reduces/eliminates *Salmonella*.

### 2.1. Cross-national web-survey of consumer households

A household on-line survey on food safety was conducted between December 2018 and April 2019 in 10 countries: Denmark, France, Germany, Greece, Hungary, Norway, Portugal, Romania, Spain and UK (Møretro et al., 2020). The survey consisted of a core module applied in all the participating countries aiming at the measurement of problematic food handling behaviour in a standardised, quantitative and cross-nationally comparable manner and specific add-on modules for France, Germany, Hungary, Norway, Portugal, Romania and the UK. The add-on module applied in Portugal was focused on “behaviours related to eggs”. Both the core and the national add-on modules were constructed in English, translated into nine languages (Danish, French, German, Greek, Hungarian, Norwegian, Portuguese, Romanian, Spanish) for the core module or to a single language for the add-ons, and then validated by native speakers (project researchers). In general, questions were defined based on a previous transdisciplinary methodology combining social sciences’ qualitative methods, such as walking-with video interviews and semi-structured observation, with a HACCP based approach, targeting the critical consumer handling steps (Fig. 1).

The core and add-on sections cover a set of questions on egg handling, including buying and preparation options, storage, cooking, leftover management, and occurrence of illness from egg consumption. Answers were collected either in the form of multiple-choice alternatives (check-all-that-apply) or on a 5-point scale ranging from 1: “Fully disagree” to 5: “Fully agree”. The demographic characteristics of the participants are presented in Table 1.

**Table 1**  
SafeConsume Household Survey: demographic characteristics of the participants in Portugal.

	%		%
Household type		<b>Gender of respondent</b>	
Single adult without children	11.4	Female	48.7
Single adult with children	3.3	Male	51.3
Couple without children	22.7	<b>Age of respondent</b>	
Couple with children	12.0	16 to 24	13.0
Other type of household without children	13.3	25 to 34	19.0
Other type of household with children	37.3	35 to 44	19.4
Vulnerable groups		45 to 54	17.8
At least one household member is pregnant	5.3	55 to 64	15.2
At least one household member with diabetes or impaired immune system	20.7	65 to 75	14.7
Men below 30 years living alone or in shared housing	1.3	More than 75	1.0
Person 16–18 years living alone or in shared housing	0.2	<b>Education level of respondent</b>	
Person 19–25 years living alone or in shared housing	1.6	Low	10.6
		Middle	37.5
		High	51.2
Tota Number of respondents (933)			

### 2.2. Statistical analysis

The sample distribution of age and education level skew significantly from the values for the Portuguese population (Table 1). The survey used a stratified sampling method, but the use of an online platform resulted in a sample that is younger and more educated than our intended target population (Portuguese population over 18 years old). While only 19.5% of the Portuguese population had a higher education degree at the time the data was collected, 51.2% of the respondents had that education level. Likewise, people who are 65 years old or more compose 25% of the Portuguese population but only 15% of the sample (INE, 2020). To obtain better estimates of the population values, we calculated a post-stratification weight variable as the ratio of the distribution of the Portuguese population at the time of the survey’s application (INE, 2020) and the survey data across three education levels (Low – completed basic education, Middle – completed secondary education, High – complete tertiary education) and six age groups (16–24, 25–34, 35–44, 45–54, 55–64, 65 years or more). We used this weight variable to adjust the response values, so that the total contribution of each weighted subgroup was similar to its share of the Portuguese population. The data analysis was performed with Python 3.7, and the libraries NumPy v1.18.0 and pandas v1.0.5.

## 3. Results and discussion

In this section we will report and discuss the critical consumer handling points (CCH) along the consumer’s journey from egg acquisition to final consumption at home, based on the framework presented in Fig. 1.

### 3.1. Egg choice at the time of purchase (CCH1)

Consumers’ egg choice plays a major role in reducing the probability of contracting salmonellosis as consumers can make choices at the point of acquisition that reduce the likelihood of bringing contaminated eggs into their homes, thus eliminating all subsequent CCHs. Table 2 presents consumers’ self-reported practices on egg choice during acquisition. Predictably, the majority of respondents opt for store-bought packaged eggs (77.1%), but there is a significant reliance on backyard eggs, both bought from local producers (16.1%) and collected from self-production (12.3%) or family and friends (19.1%). This acquisition pattern differs from that found by a survey on US consumers who declare getting their eggs mostly from stores (89.5%; Kosa, Cates, Bradley, Godwin, & Chambers, 2015). The choice between store-bought eggs and backyard eggs has an impact in reducing the probability of getting salmonellosis from the consumption of contaminated eggs. Unlike store-bought eggs that are controlled for production conditions to ensure low levels of contamination, backyard eggs can be produced in a wide (and often unknown/uncontrolled) diversity of conditions (Ferreira et al., 2020). According to Cardoso, Nicolau, et al. (2021), “the main message to consumers is to choose *Salmonella*-free eggs (those that some official entity or producer guarantees that do not contain *Salmonella*), when available, especially for dishes that are not fully heat treated”. However, backyard eggs are often prized by consumers (Whiley, Clarke & Ross, 2017) and framed as healthier, safer and closer to nature (Jackson, Ward, & Russel, 2012) than industrially produced eggs. Indeed, consumers generally perceive those eggs produced by hens raised with higher animal welfare standards as safer to eat (Rondini, Asioli, & Millan, 2020). Additionally, backyard eggs are often embedded in social and symbolic relationships, as gifting eggs and other homegrown foods is common in family/neighbourhood relationships in rural areas or between relatives living in rural and urban areas. Reciprocity embedded in a gift exchange economy is an important cultural and social norm in these communities, and eggs may be a vehicle of reciprocal relations (Riegelhaupt 1964; Ramos and Truninger, 2021).

When buying eggs, consumers recognize them, if not as a risky food,

**Table 2**  
Consumer self-reported practices on egg choice (reported percentages are weighted for age group and education level).

Survey question	Response categories	%	
The eggs I use the most are: N = 903	Store-bought (packaged)	77.1	
	Backyard eggs from family and friends	19.1	
	Bought backyard eggs (local producer, farmer's market)	16.1	
	Backyard eggs from my own chickens	12.3	
	Pasteurized eggs	1.1	
	Other	0.2	
	When buying eggs at the store, I find the following criteria important or extremely important N = 681	Best before date	92.6
		No broken eggs in the container	89.5
		Cleanliness of eggs	86.1
		Price	67.7
Origin		65.3	
Production mode (free-range, biological)		51.5	
Size		43.2	
Functional properties (Omega 3)		34.1	
Brand		21.6	
I agree with the following statement about pasteurized eggs (I don't know) N = 891		I've never heard of pasteurized eggs	37.3 (16.2)
	I don't know how to cook with pasteurized eggs	36.8 (20.4)	
	I'm not sure where to buy pasteurized eggs	32.7 (24.3)	
	Pasteurized eggs are exceedingly expensive	30.6 (39.9)	
	Food prepared with pasteurized eggs is as good as food prepared with fresh eggs	19.3 (47.1)	
	Pasteurized eggs are sold in packs that exceed my needs	17.2 (45.9)	
	Pasteurized eggs have lower nutritional value	14.5 (49.8)	
	Pasteurized eggs have too many chemicals	12.8 (50.9)	
	How do you know that the whole raw eggs you get are safe to eat? N = 915	I check the best before date	70.8
		I check if they are cracked	43.5
I trust the place where I get my eggs		29.0	
I check for health labels (e.g. <i>Salmonella</i> -free)		27.1	
I trust the egg producer		20.9	
I check if they are clean		20.8	
I trust eggs from my own country		13.1	
I check/ask about the laying date		8.0	
I buy eggs that are kept cool		3.4	
I am not concerned		0.6	
Other	4.9		
None of the above	2.2		

at least one that needs to be handled with sanitary caution. The “best before” date tops the list of criteria consumers take into account when buying eggs, being important to 92.6% of them, in line with previous surveys (Thaivalappil et al., 2020). The other two major concerns, absence of broken eggs in the container (89.5%) and cleanliness of eggs (86.1%) also relate to egg quality and safety. Dirty and cracked eggs are recognized as sources of salmonellosis and have been implicated in foodborne outbreaks (Slinko et al., 2009). It is however unknown if consumers consciously avoid cracked and dirty eggs for food safety reasons or solely for quality reasons, as clean and uncracked eggs may be more appealing. Consumers are less, but also concerned with criteria like price (67.7%), origin (65.3%) and production mode (51.5%). This corroborates Rondini et al. (2020), whom from their review on consumer behaviour, perceptions, and preferences towards eggs conclude that production method is a relevant purchase criterion, from which consumers make inferences about the health, safety, and sensory properties of eggs. Functional properties, like Omega 3 enriched eggs (34.1%), and brand (22.6%) are an afterthought for most consumers.

We also inquired consumers about their perceptions of pasteurized eggs as an alternative to fresh eggs. Pasteurized eggs are the first option for only a small number of consumers (1.1%), similarly to a previous study about egg safety practices in Australia where only 0.7% declared a preference for pasteurized eggs (Whiley et al., 2017). Pasteurized eggs are generally a poorly known product among Portuguese consumers. Most agree they never heard of pasteurized eggs or are unsure they have (53.5%) or are unsure about where to buy them (57%). Similarly, many are not aware of the characteristics of pasteurized eggs, like their price (39.9%), taste (47.1%), nutritional value (49.8%) or if they contain ‘harmful chemicals’ (50.9%).

We asked consumers how they assess the quality of the eggs they have, both at the moment of acquiring them and for eggs that have been stored at home. In both cases, very few consumers show a lack of concern for egg safety. Not surprisingly, there is an overlap between safety assessment and buying criteria, hinting that consumers treat eggs as a food product that comes with a degree of risk to manage.

Most consumers (70.8%) rely on the best before date to assess the safety of the whole raw eggs at the moment of buying but that does not exclude the visual inspection of the eggs for cracks (43.5%) or cleanliness (20.8%). For some users, trust in the food production and distribution system is also an important element in that assessment, being at the level of the egg producer (20.9%), the seller (29%) or that of national food system (13.1%). The higher trust attributed to the people from whom the respondents buy their eggs, when compared to trust in the national food system as a guarantee of product safety, is in line with Kjaernes et al. (2007)'s findings describing Portuguese consumers as tending to trust interpersonal relationships more than institutional actors.

### 3.2. Eggs hygiene and storage (CCH2 and CCH3)

Consumers can reduce the level of pathogens in food with hygienic handling and storing at low temperatures. Storing eggs in the refrigerator will stop the growth of *Salmonella* in contaminated eggs (Bradshaw, Shah, Forney, & Madden, 1990; Lublin & Sela, 2008). For this set of questions, we have asked how consumers handle both backyard (B) and store-bought (S) eggs to check for any practices related to egg storage that might increase the level and growth rates of *Salmonella* in contaminated eggs (Table 3).

Most consumers store their eggs in the fridge and are more likely to store them in the fridge door (45.1% D, 48.4% S), where the exposure to fluctuations in temperature from the fridge door being opened results in condensation on the eggshells and raises the risk of eggshell penetration by *Salmonella* and growth in the egg content (De Reu et al., 2005). It is important to note that many fridges have an egg container at the door, a material ‘script’ (Akrich, 1997) embedded in fridge equipment design that configures its intended use; making consumers intuitively to place eggs at the door. Nevertheless, a lesser but still relevant percentage of consumers reported not keeping their eggs in the refrigerator and this practice is more common for backyard eggs (23.6%) than for store-bought eggs (14.7%), likely based on a belief that backyard eggs should be stored at room temperature. In agreement with Regulation (EC) No 853/2004, in Portugal, industrial eggs are kept at room temperature since collection until the time of purchase. Therefore, storing these eggs in the refrigerator will have a major impact on quality and a less important impact on safety; for internally contaminated eggs, high levels of *Salmonella* may be reached at the time of purchase because *Salmonella* grows rapidly in the egg yolks stored at room temperature. In contrast, backyard eggs must be stored in the refrigerator as soon as possible after laying as *Salmonella* grows fast at room temperature if present in the egg yolk (Lublin & Sela, 2008).

Despite eggs coming in their own package, consumers follow the technology script of storing the eggs in storage trays that come with the fridge, some built in the fridge door, which increases the probability of transmitting *Salmonella* present in the shell between consecutive egg

**Table 3**

Consumer self-reported practices of egg storage (reported percentages are weighted for age group and education level).

<sup>a</sup> Survey question	Response categories	Backyard (%)	Store-bought (%)	
Where do you store your eggs? N = 401 (B); 681 (S)	Fridge door	45.1	48.4	
	Fridge shelf	31.3	36.8	
	In a cool place (pantry, cellar, garage)	20.1	11	
	Out of the fridge	3.5	3.7	
What kind of container do you use to store them? N = 401 (B); 681 (S)	Egg container	61.7	50.6	
	Egg cartons	37.8	48.7	
	Other	0.5	0.7	
Usually how long do you keep a backyard egg? N = 401	Less than a week	37.5	–	
	2 weeks	35.8	–	
	3 weeks	14.4	–	
	4 weeks or more	8.4	–	
What do you do with store-bought eggs beyond their best before date? N = 903	Throw them away	–	47.7	
	Use them if it doesn't float in water	–	27.2	
	Use them if the inside looks good	–	22.1	
	Use them if I plan to cook them thoroughly	–	4.3	
	Use them within 1 week	–	12	
	Use them within 2 weeks	–	1.2	
	Use them without hesitation	–	3.1	
	How do you know that the whole eggs you already have at home are safe to eat? N = 915	I keep them in the fridge	49.1	
		I put one in water and check if it floats	45.1	
		I check the best before date	43.1	
I know how long I can keep eggs for		34.6		
I check if they are cracked		26		
I crack an egg and smell it		18.8		
I trust the place where I get my eggs		13.9		
I check if they are clean		10.9		
I do a spinning test		10.1		
I trust eggs from my own country		8.8		
I trust the egg producer	I trust the egg producer	8.3		
	I am not concerned	0.6		
	Other	1.1		
	None of the above	0.3		

<sup>a</sup> (B), backyard eggs; (S), store-bought eggs.

batches if the tray is not properly washed in-between and leaves eggs exposed to higher and less stable temperatures. In fact, many consumers (B: 61.7%, S: 50.6%) favour these built-in storage trays to egg cartons to store their eggs. To avoid egg storage mishandling, in-built egg storage trays should be revised in fridge design to accommodate safer consumer handling.

For store-bought eggs, 47.7% of consumers use them only if within their best before date, disposing them after that date. Even though only a small minority declared using the eggs beyond their best before date without hesitation (3.1%), many do so by relying on risk mitigation measures: by evaluating the egg's condition - with the float test (27.2%), visual inspection (22.1%) - or by limiting the time frame in which they consume the eggs to one week (12%). While popular, these measures are not necessarily reliable to detect contaminated eggs and increase the

probability of using contaminated eggs if these were not stored at adequate temperatures. This is of particular concern for recipes with raw or undercooked eggs, which are common in Portuguese cuisine. For backyard eggs, that do not have a stamped best before date, most consumers keep them for a short time, 37.5% for no more than a week and 35.8% for no more than two weeks.

While 43.1% of consumers rely on the best before date to assess the safety of the eggs they have at home, most are more concerned with the way their eggs are stored, with 49.1% of consumers declaring they trust their eggs because they are kept in the fridge. Additionally, consumers rely on a set of tests and inspection methods to check for the eggs' condition, most notably by checking if eggs float in water (45.1%), but also by inspecting them visually for cracks (26%) or cleanliness (10.9%) or by smelling them before use (18.8%).

When it comes to the hygienic handling of eggs (Table 4), consumers

**Table 4**

Consumer self-reported practices (%) of egg hygiene (reported percentages are weighted for age group and education level).

<sup>a</sup> Survey question	Response categories	Backyard (%)	Store-bought (%)
Before storing eggs ... N = 401 (B); 681 (S)	I always wash and clean them	36.0	17.3
	I wash or clean them if they look dirty	32.7	31.3
	I never wash or clean them	31.2	50.1
I clean eggs before storing them by ... N = 265 (B); 315 (S)	Rinse and dry them	61.2	54.3
	Rinse them without drying	22.5	28.1
	Using a damp paper or cloth	16.3	17.6
Do you clean the eggs before using them? N = 915	Every time	34.8	
	If they look dirty	34.4	
	Depending on where I got them	7.3	
	I don't clean eggs	22.4	
	Other	1.1	
How do you clean eggs before using them? N = 703	Running tap water	87.1	
	Kitchen roll or cloth	8.9	
	Detergent/disinfectant	4.6	
	Scouring pad or sandpaper	5.2	
	Antibacterial wipes	3.1	
How likely is it that you would touch the whole eggs with your bare hands while storing them? N = 933	Other	0.4	
	None of the above	1.2	
	Unlikely	33.3	
	Some possibility	12.1	
	Fairly good possibility	12.5	
How likely is it that you would wash your hands (with soap or detergent) immediately after touching the egg during storage? N = 933	Very probable	9.5	
	Almost sure	29.8	
	Unlikely	30.3	
	Some possibility	16.9	
	Fairly good possibility	16.9	
How likely is it that you would wash your hands (with soap or detergent) immediately after touching the eggs before using them? N = 933	Very probable	11.0	
	Almost sure	21.7	
	Unlikely	27.3	
	Some possibility	13.5	
	Fairly good possibility	18.1	
If you spilt a bit of egg, how likely is it that you would immediately clean up the spillage (with detergent)? N = 933	Very probable	15.7	
	Almost sure	22.3	
	Unlikely	7.7	
	Some possibility	7.2	
	Fairly good possibility	17.2	
Very probable	Very probable	14.2	
	Almost sure	50.7	

<sup>a</sup> (B), backyard eggs; (S), store-bought eggs.

are more likely to wash or clean backyard eggs (68.7%) before storage than store-bought eggs (48.6%). Even though cleaning eggs removes dirt and microbial contaminants from the eggshell (Hutchison et al., 2004; Messens, Gittins, Leleu, & Sparks, 2011), the benefits of rinsing the eggs are still a controversial issue as this might deliver contaminants through the shell, especially if the eggs are not dried after. In fact, while most consumers who clean their eggs also dry them after washing (61.2% B, 54.3% S), about a quarter do not (22.5% B, 28.1% S). Overall, consumers are about as likely to clean their eggs just before use (in the case of backyard eggs) as they are before storage, either always (34.8%) or only if they look dirty (34.4%), usually by rinsing them in water (87.1%).

In a scale of likeliness of touching eggs with bare hands during handling, about a third of consumers (31.4%) declare being almost sure to touch raw eggs with their bare hands as they store them and 30.1% declare that they are unlikely to wash their hands when that happens. Similarly, 27.3% declare they are unlikely to wash their hands after handling eggs during preparation. We also highlight that many of the consumers report these actions being either unlikely (touching: 33.3%, washing hands after touching: 30.3%, washing hands after preparation: 27.3%) or almost certain (29.8, 21.7%, 22.3%); that is, they either always do or never do, hinting that these minor actions are often routinized and performed by people during food preparation in an unreflective and distracted way. As stated in section 3, infection can occur through ingestion during preparation by someone touching their mouth with their hand (an often-performed unintentional action) after touching raw egg. Infection can thus arise from a sequence of actions that are routinized and that in isolation are hard for consumers to recognize as being risky.

### 3.3. Egg preparation and consumption (CCH4 to CCH6)

In this step, consumers can reduce the hazard by thermal or chemical inactivation. Inactivation can vary widely with the way eggs are handled during this phase, by how thoroughly cooked the eggs are – runny undercooked eggs represent a larger risk than firm, well done eggs. The results (Table 5) show a high prevalence of cooking recipes using raw or undercooked eggs as has also been identified in other countries (Patil et al., 2005; Thaivalappil et al., 2020). However, this profile of cooking methods reflects both food cultural conventions and health concerns in Portugal. Boiled eggs, which are consumed at least once a month by 96.4% of the respondents, are an integral element of many popular dishes, most notably to accompany boiled fish, in chicken soup, or as ingredients in a cold tuna salad. We believe boiled eggs may benefit from being seen by consumers as a healthy option for eating eggs, when compared to other cooking methods like fried (83.7%), scrambled (79.6%) or omelettes (82.5%) that rely on incorporating fats such as oil

or butter, or to poached eggs (55.3%) that are more usually cooked in sauce or soup than in water. Dishes using raw or undercooked eggs are not as frequently consumed but main dishes such as codfish à Brás (63.2%), a dish of codfish and shoestring fries incorporated into lightly cooked scrambled eggs, and desserts such as chocolate mousse or *baba de camelo*, a condensed milk mousse (37.0%), that are often prepared with raw eggs, are still a common occurrence in Portuguese meals.

Given the role of proper cooking in preventing infection we have also asked consumers how their eggs are usually cooked, for boiled and fried eggs. Respondents were presented with a set of pictures (Table 6) and asked to identify which resembles more a boiled and fried egg as they usually eat at home. Results show a contrast in preference for boiled and fried eggs. While consumers prefer hard boiled eggs (Boiled eggs 3 and 6), they prefer their fried eggs with an undercooked yolk (Fried eggs 2, 1 and 3). This contrasts with other countries, where it is common to fry eggs on both sides or to eat soft-boiled eggs. In a survey of Finnish consumers (Lievonen, Havulinna, & Maijala, 2004) only 27.9% of respondents cooked eggs on one side (sunny-side-up) and almost half (44.3%) preferred their eggs soft-boiled; while in a survey of US consumers 46% of respondents fried eggs until the yolk is firm (Kosa et al., 2015). These practices are related to consumers' culinary repertoires and a shared understanding of how food should be prepared and presented that diverges from other national cultures. In Portugal, hard boiled eggs hold their shape and fit their usual role as an ingredient to be added to salads or soups. Eggs are also often cooked along with vegetables (potatoes) or fish (cod) whose cooking times are usually sufficient to thoroughly cook the yolk. Fried eggs, on the other hand, are very often served on top of a steak (*bitoque*) or a meat and cheese sandwich (*francesinha*), usually alongside fries. Culinary speaking, there is a proper way to eat a fried egg that involves dipping bread (that is often present at Portuguese tables during meals) or fries in the yolk as the dish arrives at table. A fried egg with solid yolk is usually considered to be improperly cooked. Eating a fried egg is linked to a particular experience of tasting food, where the runny egg is employed as a dip sauce, turning the dish less dry.

This cooking repertoire is concerning when combined with risk prone practices during egg storage (CCH3) identified in section 3.2, increasing the risk of a raw or undercooked contaminated egg to be ingested. Almost a quarter of consumers (23.6%) store their backyard eggs outside the fridge and 58% of them (or 13.8% of all respondents) do so for two weeks or more. While store-bought eggs are generally safe to eat beyond their best before date if kept inside the fridge, 8.3% of consumers put their store eggs outside the fridge and consume them after their best before date.








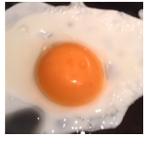

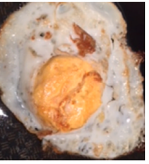

Continuing to examine egg cooking practices, we asked respondents how do they check if their eggs are done, taking into account they might use more than one method (Table 7). We found that most consumers use

**Table 5**

Consumer self-reported frequency (% weighted for age group and education level) of egg consumption by cooking method (N = 903).

How often do you eat ...	Boiled eggs	Scrambled eggs	Fried Eggs	Omelette	Poached eggs	Dishes using raw/ undercooked eggs	Deserts using raw/undercooked eggs	Homemade mayonnaise	Very moist cakes	Raw cake dough	Eggnog
Never	0.9	6.1	3.6	3.2	19.1	13.3	24.5	45.4	37.0	44.9	70.2
At least once a year	2.6	13.1	12.8	14.2	25.5	23.5	38.5	30.6	40.9	19.7	16.7
At least once a month	26.0	28.1	32.0	33.0	25.9	33.4	27.7	13.4	13.9	21.5	5.5
At least every 2 weeks	21.0	20.8	21.4	21.9	13.9	17.2	6.1	4.9	5.7	7.9	3.9
At least once a week	36.0	22.5	25.1	22.7	14.2	10.5	2.2	2.5	1.2	4.1	1.8
Several times a week	13.4	8.2	5.2	4.9	1.3	2.1	1.0	3.1	1.3	1.7	2.0
Total frequency ≥ At least once a month	96.4	79.6	83.7	82.5	55.3	63.2	37.0	23.9	22.1	35.2	13.2

**Table 6**  
Consumer visual preferences of egg doneness (% weighted for age group and education level).

Which of the following boiled eggs is more like those you usually eat? n = 862						
%	58.9	35.8	2.4	1.2	1.1	0.6
Which of the following fried eggs is more like those you usually eat? n = 748						
%	39.7	26.9	24.1	5.5	3.8	

**Table 7**  
Consumer self-reported practices of egg cooking (reported percentages are weighted for age group and education level).

Survey question	Response categories	%
How do you check eggs for doneness? N = 903	Cooking time	49.3
	I trust my experience	38.7
	Yolk's colour	37.8
	Yolk's firmness	29.3
	Firm and opaque whites	28.7
	I use a toothpick	5.4
	I use a thermometer	1.7
	Other	0.2
When you are preparing egg, dishes do you follow recipes from any of these places? N = 903	I don't check	3.8
	Internet	58
	Cooking books/magazines	50.4
	Family and friends	39.9
	TV shows	24.7
	Product labels	16.6
I agree or agree completely with the following affirmation about how I use recipes N = 796	Other	0.9
	I never follow recipes	18.4
	I follow the instructions to check the food for doneness	79.6
	I follow the cooking time indications	77.9
	I follow the temperature indications	77.6
	I follow the ingredient indication	72.3
	I follow the quantity indications	70.4
I follow the presentation indications	64.5	
I prepare the dish exactly as described	59.5	

at least one method for checking the egg's doneness, more commonly by relying on cooking time (49.3%), but also on visual cues, like the yolk's colour (38.7%), firmness (29.3%) and/or the white's colour (28.7%). Using a toothpick to check if a cake (prepared with eggs) is done (5.4%) or using a thermometer (1.7%) to get a more viable reading of the egg's doneness are niche practices. This result is in line with another survey that found that 50% of respondents never considered using a thermometer and 25% weren't aware they could use temperature to check for egg doneness (Kosa et al., 2015). The fact that temperature is not part of the usual set of techniques to check for egg doneness is further illustrated by a study of egg recipes finding mentions or recommendation for temperature to be uncommon – recipes usually rely on either time or visual inspection of the egg (Godwin, Maughan, & Chambers, 2016). However, some consumers report not using any method to check for doneness, relying only on their experience (11.6%) and 4.5% declare not checking for doneness at all.

We also asked consumers about their use of recipes when cooking eggs. Consumers are mostly getting recipes from the internet (58%). However, traditional sources like cooking books/magazines (50.4%) and family and friends (39.9%) still play an important role in sharing recipes. Only 59.5% of consumers declared following the recipe exactly as described, but they more often follow those indications that might have more impact on microbiological safety, like doneness (79.6%), cooking time (77.9%) and temperature indications (77.6%). These results show recipes are another way to help consumers adopt safe food handling practices by presenting them not only as abstract advice that consumers might struggle to fit into their cooking routines, but as embedded into the process of preparing a meal.

**Table 8**  
Consumer self-reported practices of egg leftover storage (reported percentages are weighted for age group and education level).

Survey question	Response categories	%
Consider unheated side dishes that are prepared with raw eggs and which are not fully heated up during preparation. How likely is it that there are leftovers you will keep? N = 933	Unlikely	64.6
	Some possibility	11.9
	Fairly good possibility	10.1
	Probable	6.0
	Very probable	4.4
Consider dishes that are prepared with raw eggs alone and which are not fully heated up during preparation. How likely is it that there are leftovers you will keep? N = 933	Unlikely	71.4
	Some possibility	9.7
	Fairly good possibility	7.4
	Probable	4.4
	Very probable	4.0
Consider sweet dishes that contain raw eggs, and which are not fully heated up during preparation. How likely is it that there are leftovers you will keep? N = 933	Unlikely	35.8
	Some possibility	17.0
	Fairly good possibility	23.6
	Probable	7.6
	Very probable	13.0
When you boil eggs and don't eat them all, what do you do with the leftovers? N = 862	Store them in the fridge	68.2
	Store them outside the fridge	7.4
	Throw them away	20.8
	Other	3.7
When you cook dishes with raw or undercooked eggs and don't eat everything, what do you do with the leftovers? N = 560	Store them in the fridge	79.8
	Store them outside the fridge	4.2
	Throw them away	14.6
	Other	1.4
How long after you made the original dish (and you did not freeze the leftovers) do you typically still eat the leftovers of such dishes that were made with raw eggs and not fully heated up during preparation? N = 933	Up to 1 day (or no leftovers or in-home consumption)	70.9
	2-3 days	24
	4 days or more	5.2

### 3.4. Storage of egg dish leftovers (CCH3)

We asked consumers about how they manage leftovers of egg dishes (Table 8). Consumers can reduce the risk by properly storing egg dish leftovers. However, safe management of leftovers may require the disposal of food due to the risk of contamination, which conflicts with concerns over food waste; a major food related concern among Portuguese consumers (Truninger et al., 2019). Storage is not a widespread practice, as most consumers declare to be unlikely to keep leftovers of dishes (74.2%) or side dishes (66.4%) using raw eggs. Notwithstanding, it is more common for desserts prepared with raw eggs - 44.2% of consumers declare at least a fairly good possibility to spare these leftovers. This disparity might come from the different practices for day-to-day cooking - for most egg dishes - and for the preparation of desserts, usually reserved for special occasions like parties or family reunions. Daily meals are often prepared in portions aimed at the members of the household while many of the desserts using raw eggs (*chocolate mousse*, *baba de camelo*) are usually prepared in large doses in advance to later be served individually, which can easily lead to leftovers. Still, when it comes to leftovers, consumers handle boiled eggs and dishes using undercooked eggs similarly, even if the latter are more likely to carry a health risk. Most consumers store these leftovers in the fridge (68.2% boiled eggs, 79.8% undercooked recipes) and only a minority throws them out after being served - 20.8% for boiled and 14.6% for dishes with undercooked eggs. When it comes to storage time of these leftovers, only a few consumers (5.2%) store them for longer than three days.

### 3.5. Knowledge about eggs as a cause of foodborne salmonellosis

One last set of questions enquired consumers about their understanding of the connection between eggs and foodborne illness (Table 9). When asked if eggs can cause foodborne illness, close to half of

**Table 9**  
Consumer's perceptions of egg related foodborne illness (reported percentages are weighted for age group and education level).

Survey question	Response categories	%
In your opinion, can eggs bought in stores cause foodborne illnesses? N = 903	No	21.3
	Don't know	31.6
In your opinion, can backyard eggs cause foodborne illnesses? N = 903	No	21.9
	Don't know	28.0
Which of the following microorganisms do you associate with eggs? N = 903	<i>Salmonella</i>	65.8
	<i>E. coli</i>	10.6
	<i>Toxoplasma</i>	3.9
	<i>Listeria</i>	3.7
	<i>Norovirus</i>	1.9
	<i>Campylobacter</i>	1.7
	None	1.6
	Don't know	26.6
Have you ever been sick after eating the following egg products? N = 903	Never been sick from eating eggs	72.2
	Don't know	15.2
	Pastry cakes	3.6
	Boiled eggs	3.2
	Fried eggs	3.0
	Mayonnaise	3.0
	Codfish à Brás	2.0
	Chocolate mousse	1.7
	Omelette	1.1
	Eggnog	0.5
	Other	0.8
When you became sick, where were these products consumed? N = 161	At home	44.0
	Café or restaurant	43.0
	Canteen	19.3
	Celebration (wedding, birthday party)	11.8
	Other	1.9

the respondents either do not think egg consumption can be responsible for illnesses or are not sure enough to give an answer (Table 3). These results show a lower level of awareness of the risks of contaminated eggs than found in previous studies in other countries- in Canada 64% of consumers identified eggs as a high-risk food (Murray et al., 2017) and in the USA 73% perceived eggs as likely to contain harmful microorganisms (Lando, Verrill, Liu, & Smith, 2016). Only a small minority (1.6%) does not associate eggs with any of the listed pathogens, but about a quarter of consumers (26.6%) are not sure about which pathogens to be associated with eggs. When it comes to associating eggs with *Salmonella* contamination, 65.8% were able to correctly do so. In previous studies the majority (>90%) of consumers declared having heard of *Salmonella*, often more frequently than other food related pathogens (Henke, Alter, Doherr, & Merle, 2020; Kennedy et al., 2005; Lando et al., 2016; Van Velsen, Beaujean, Van Gemert-Pijnen, Van Steenberghe, & Timen, 2014). However, not all these consumers were necessarily able to associate *Salmonella* with the particular foods where it might be found - in the Netherlands, only 61% associated *Salmonella* specifically with chicken and raw vegetables (Van Velsen, Beaujean, Van Gemert-Pijnen, Van Steenberghe, & Timen, 2014) and in Ireland 44% associated *Salmonella* with eggs (Kennedy et al., 2005).

Most consumers lack direct experience with egg related foodborne illness. A wide majority (72.2%) declares to have never been sick after eating eggs and 15.2% are not sure if they ever did. Among those who report having been sick, it happened more frequently after eating pastry cakes (3.6%) and boiled eggs (3.2%), followed by fried eggs (3%) and mayonnaise (3%). Codfish à Brás and chocolate mousse are less reported options, hinting that some consumers might not be as aware of the risk of *Salmonella* ingestion if these dishes are prepared with contaminated eggs. Even if many cases of illness have occurred at home (44%), they have occurred more frequently outside, either at cafés or restaurants (43%), canteens (19.3%) or celebratory rituals such as weddings (11.8%).

### 3.6. Practical recommendations

Our survey shows that even if many consumers aren't aware of the risks of foodborne illness from contaminated eggs, most seem aware there is a risk associated with egg consumption at home. When selecting eggs, consumers give priority to "best before" dates and to being able to check the cartons for cracked or dirty eggs. Moreover, they apply a diversity of safety assessment practices for dealing with the eggs they have at home. Even if some of these methods might not be effective, the responses to these questions add up to an indication that consumers understand eggs as a product that should be handled with sanitary precaution and thus might be receptive to interventions to reduce risk in egg handling.

Information campaigns highlighting the health risks present in egg handling and providing safety recommendations that consumers can implement at home are one important tool in reducing the burden of *Salmonella* in Europe. However, they are not enough, given the adoption of practices by consumers that reduce microbiological risk can easily compete with other health concerns like pesticide use on food crops and antibiotics on animal production (Miles & Frewer, 2001; Truninger, 2019) or with more pressing daily concerns, like having a family meal ready on time or avoiding food waste (Holm, 2003; Meah, 2014). Moreover, global food safety messages not taking into account the cultural, social, and economic specificities may not be effective.

Information campaigns can thus be more effective at promoting safer egg handling practices if informed by an understanding of consumers' practices in their cultural, material and practical contexts. For example, information about backyard eggs having a higher risk of being contaminated would compete with representations of non-industrial food production as coming from trusted local sources and not involving the use of substances perceived as harmful (Jackson, 2010; Roslyng, 2011). It might prove effective to complement consumer



education on risk mitigation strategies with an effort to improve consumer trust in industrial egg production (and in pasteurized eggs in particular), to encourage consumers to look for eggs with a guarantee of being *Salmonella* free for raw or undercooked egg dishes. However, many of these aspects are not dependent on consumers, but on egg manufacturers' practices, business models and regulatory food systems. Unfortunately, eggs with such *Salmonella* free guarantees are only available in a few countries. Similarly, recommendations to consumers on new cooking methods might clash with shared notions of propriety around food (for example, fried eggs having runny yolks), with common cooking and serving practices in restaurants, and with an established cooking repertoire as consumers rely on peer communities (family/friends, the internet) and cookbooks for recipes, that might not align with the recommendations from food safety experts (Godwin et al., 2016). Moreover, consumers alone should not bear the responsibility for changing practices. Better design of domestic technologies (e.g., fridge) should be promoted in order to facilitate safer consumer practice.

#### 4. Conclusion

This study aimed to analyse food safety related to egg consumption at home using a novel framework, Critical Consumer Handling (CCH). CCH was developed for the SafeConsume project by a transdisciplinary team specifically to analyse safe food handling practices at home. We were able to identify unsafe egg handling practices that can be targeted in order to reduce the health burden of *Salmonella*. During the procurement phase, many consumers have a preference for backyard eggs, that can be produced in a wide range of conditions and generally are not controlled for the presence of *Salmonella* and thus, present a risk of contamination if consumers disregard other safety practices down the CCH chain. There is a significant ratio of consumers who store their eggs outside the fridge and they are more likely to do so for backyard eggs, potentially leading to conditions for *Salmonella* to multiply if the eggs are contaminated. Hygiene during handling is also an issue as many consumers touch the eggs at several stages of handling without washing hands with soap afterwards. Finally, while Portuguese consumers do not often prepare dishes or desserts based on raw or undercooked eggs, they show a heavy preference for undercooked fried eggs, that they consume quite frequently. To address these concerns, possible interventions should prioritize shifting consumers' acquisition practices towards eggs with lower probability of being contaminated with *Salmonella*. The use of *Salmonella*-free eggs (those that some official entity or producer guarantees that does not contain *Salmonella*) would eliminate subsequent CCH points. For dishes containing raw or undercooked eggs, the use of industrially produced eggs, clean eggs stored refrigerated in the shop, backyard eggs collected and refrigerated soon after laying or pasteurized eggs should be recommended. Considering that *Salmonella* might be present in a significant share of domestic eggs in Portugal, these recommendations may play a key role in the prevention of *Salmonella* infection and reduce risk during food preparation at home. However, to overcome the barriers to widespread adoption of food safety practices, it is essential that food safety awareness campaigns are sensible to the variations in family dynamics and consumers' practices according to material, economic, social and cultural factors. It is therefore important for future research to focus not only on how the unsafe egg handling practices identified in this study vary across different social groups but also on highlighting the ways in which they are intertwined with consumers' routines and socio-cultural meanings and expectations of quality eggs.

#### CRedit authorship contribution statement

**Luís Junqueira:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **Mónica Truninger:** Conceptualization, Funding acquisition, Project administration, Writing – original draft, Writing – review & editing. **Valérie L. Almlí:**

Conceptualization, Funding acquisition, Writing – review & editing. **Vânia Ferreira:** Conceptualization. **Rui Leandro Maia:** Conceptualization, Formal analysis, Writing – review & editing. **Paula Teixeira:** Conceptualization, Funding acquisition, Project administration, Writing – original draft, Writing – review & editing.

#### 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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