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Report of the Scientific Committee of the Spanish Agency for Food Safety and Nutrition (AESAN) on the conservation conditions of foods made with eggs or egg products in retail establishments

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Working group

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Abstract

Royal Decree 1021/2022, which regulates certain hygiene requirements for the production and marketing of foodstuffs in retail establishments, establishes that, in retail establishments, food made with raw egg subjected to heat treatment where a temperature equal to or greater than 70 ºC is reached for 2 seconds in the centre of the product or any other combination of time and equivalent temperature conditions and which are not stable at room temperature, as well as foodstuffs made with egg products to be consumed without undergoing heat treatment, must be stored at

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a temperature equal to or lower than 8 ºC and must be consumed within a maximum of 24 hours following their preparation. Also, in our country's retail establishments, the use of raw eggs for foodstuffs that are not going to be subjected to heat treatment is not allowed.

Against this background, the Scientific Committee of the Agency for Food Safety and Nutrition (AESAN) has been requested to evaluate the safety of conservation of foodstuffs made with raw eggs and subjected to a heat treatment, as well as those foods that are not subjected to a heat treatment made with pasteurized egg products at storage temperatures of prepared meals (in particular, at 4 ºC if their shelf life is greater than 24 hours, considering that Royal Decree 1021/2022 already allows storage at a temperature equal to or lower than 8 ºC for a maximum of 24 hours). Furthermore, it has been requested to evaluate the risk of foodborne infection, in the field of catering, due to the consumption of raw eggs contaminated both internally and externally with *S.* Enteritidis and *S.* Typhimurium.

The AESAN Scientific Committee, through the application of predictive models, concludes that the refrigeration conservation conditions stipulated in Royal Decree 1086/2020 for prepared foods (4 ºC if their shelf life is more than 24 hours and 8 ºC if their shelf life is less than 24 hours) are sufficiently safe with respect to the risk of proliferation of *Salmonella* spp. in foods made with raw eggs and subjected to heat treatment, as well as in those not subjected to heat treatment made with pasteurized egg products, provided that the starting microbiological quality is guaranteed, as well as good hygiene and handling practices.

Moreover, although the prevalence of *S.* Enteritidis and *S.* Typhimurium in operations involving laying hens is currently low, the risk associated with the consumption of raw egg preparations can be considered low but not negligible. In the context of catering, the combination of a reduced but persistent prevalence, together with the high capacity to spread the pathogen and the severity of the associated cases, makes it necessary to maintain a preventive management approach based on the strict application of good hygiene practices, continuous refrigeration and the preferential use of pasteurised egg products.

Key words

Egg, egg products, retail establishments, conservation, refrigeration, *Salmonella*.

Suggested citation

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1. Introduction

Before the publication of Royal Decree 1021/2022 (BOE, 2022), which regulates certain hygiene requirements for the production and marketing of food products in retail establishments, the requirements for foods for immediate consumption made with eggs, in retail establishments, were set out in Royal Decree 1254/1991 (BOE, 1991). This sets out rules for the preparation and preservation of home-made mayonnaise and other foods for immediate consumption in which eggs are listed as an ingredient. This rule, already repealed, established that when the food was not subjected to heat treatment at a minimum of 75 ºC in its central part, eggs had to be replaced by egg products. It also set the temperature and maximum storage time of food for immediate consumption with egg or egg products as an ingredient (8 ºC, maximum 24 hours). However, in practice, foods made with raw eggs that do not reach 75 ºC are found in retail establishments (fried eggs with an uncooked yolk, uncooked omelettes, etc.).

Taking into account the situation up until then, during the drafting phase of Royal Decree 1021/2022 (BOE, 2022), the Scientific Committee of the Spanish Agency for Food Safety and Nutrition (AESAN) was consulted, and it prepared a Report of the Scientific Committee of the AESAN on the time-temperature combinations necessary for the safe cooking of foods and adequate temperatures for the hot-holding and reheating of cooked foods (AESAN, 2021). This report established the following conclusions regarding foods made with eggs:

- The appropriate time-temperature combination for safe cooking of foods made using eggs is 70 ºC for 2 seconds (or equivalent treatment). This internal temperature is necessary so as not to require the use of pasteurised egg products, with subsequent maintenance at 8 ºC for a maximum of 24 hours.
- Different preparations such as fried eggs or lightly cooked omelettes must be cooked so that the centre of the product reaches 63 ºC for 20 seconds (or equivalent treatment), provided that they are served for immediate consumption.

However, the Scientific Committee was not asked for its opinion on the storage conditions of foods with egg/egg products as an ingredient, so the conditions set out in the previous regulations were maintained.

The conclusions of this report were introduced in Article 9 of Royal Decree 1021/2022 (BOE, 2022):

"Article 9: Specific requirements for foods made with eggs.

1. Retail establishments may use raw eggs to make foods that:
   a) Are subjected to heat treatment where the centre of the product reaches a temperature equal to or greater than 70 ºC for 2 seconds or any other combination of time and temperature conditions with which an equivalent effect is obtained.
   b) Are subjected to heat treatment where the centre of the product reaches a temperature of 63 ºC for 20 seconds and are served for immediate consumption, such as fried eggs, omelettes or other preparations.
2. To elaborate products that are to be consumed without undergoing heat treatment that meets the conditions of paragraph 1, the raw egg must be replaced by egg products from approved establishments.

3. Foods processed in accordance with the provisions of sections 1.a), which are not stable at room temperature, and in accordance with section 2, must be stored at a temperature equal to or lower than 8 ºC and consumed within a maximum of 24 hours after preparation. The date and time of preparation must be recorded."

However, the application of this Article limits the maintenance to a temperature equal to or lower than 8 ºC for a maximum of 24 hours, which does not allow certain foods to be kept at the storage temperatures that prepared meals are kept at. These are included in Article 30 of Royal Decree 1086/2020 (BOE, 2020) which regulates and makes flexible certain conditions of application of the provisions of the European Union on the hygiene of the production and marketing of food products and regulates activities excluded from its scope of application. These temperatures for storing prepared meals are:

- Hot: above or equal to 63 ºC.
- Refrigerated: equal to or less than:
  - 4 ºC if their shelf life is greater than 24 hours.
  - 8 ºC if their shelf life is less than 24 hours.
- Frozen: equal to or lower than -18 ºC.

Also, in our country's retail establishments, the use of raw eggs is not permitted for foodstuffs that are not going to be subjected to heat treatment, as established in Article 9 of Royal Decree 1021/2022. However, when reviewing the legislation applicable to retail establishments in other Member States, we note that some of them, such as Estonia, France, Austria, Portugal, Romania or Slovenia, do not impose restrictions on the use of raw eggs in this type of preparation. Other Member States allow it as long as a number of requirements are met, but none apply restrictions that are as strict as those in Spain.

Taking into account the prevalence of *Salmonella* and the reduction targets both in Spain and in the rest of the Member States, as well as the control measures applied in our country and in other Member States, we consider it appropriate to evaluate the possibility of reviewing the national regulations with the aim of assessing whether it is possible to make these requirements more flexible based on a risk assessment.

Considering that an amendment to Royal Decree 1021/2022 (BOE, 2022) is currently being worked on to improve its application, a risk assessment is required to provide a solid scientific basis for the amendment of the standard in relation to the aspects set out above.

Therefore, a report has been requested from the Scientific Committee of the AESAN which assesses the following points:

- The safety of storing foods made with raw egg (omelette, scrambled eggs, flans, etc.) and subjected to a heat treatment where the centre of the product reaches a temperature equal to or greater than 70 ºC for 2 seconds, or equivalent treatment, at the storage temperatures of prepared meals (in particular, at 4 ºC if their shelf life is greater than 24 hours, considering that

Royal Decree 1021/2022 (BOE, 2022) already provides for storage at a temperature equal to or lower than 8 ºC for a maximum of 24 hours).

- The safety of storing foods that are not subjected to heat treatment made with pasteurised egg products (tiramisu, mayonnaise, etc.) at the storage temperatures of prepared meals (in particular, at 4 ºC if their shelf life is greater than 24 hours, considering that Royal Decree 1021/2022 (BOE, 2022) already allows storage at a temperature equal to or lower than 8 ºC for a maximum of 24 hours).
- Given the current prevalence of *Salmonella* Enteritidis and *Salmonella* Typhimurium in flocks of laying hens and considering the requirement to keep eggs refrigerated until cracked for use in dishes intended to be consumed immediately on-site, assess the risk of food infection, in catering establishments, due to consumption of raw eggs internally contaminated with *S.* Enteritidis and *S.* Typhimurium. What would the risk be if the egg were externally contaminated?

2. Background

2.1 Regulations applicable to prepared meals prepared in catering establishments: particular case of eggs

Article 9 of Royal Decree 1021/2022 (BOE, 2022) regulates specific requirements on the hygiene of egg production and marketing in retail establishments. It states that:

1. Retail establishments may use raw eggs to make foods that:
   a) Are subjected to heat treatment where the centre of the product reaches a temperature equal to or greater than 70 ºC for 2 seconds or any other combination of time and temperature conditions with which an equivalent effect is obtained.
   b) Are subjected to heat treatment where the centre of the product reaches a temperature of 63 ºC for 20 seconds and are served for immediate consumption, such as fried eggs, omelettes or other preparations.
2. To produce products that are to be consumed without undergoing heat treatment that meets the conditions of paragraph 1, the raw egg must be replaced by egg products from approved establishments.
3. Foods processed in accordance with the provisions of sections 1.a), which are not stable at room temperature, and in accordance with section 2, must be stored at a temperature equal to or lower than 8 ºC and consumed within a maximum of 24 hours after preparation. The date and time of preparation must be recorded.

On the other hand, Article 30 of Royal Decree 1086/2020 regulates the storage temperatures of prepared meals (in general), establishing the following limits:

- Hot: temperature above or equal to 63 ºC.
- Refrigerated: temperature equal to or lower than 4 ºC, if its shelf life is greater than 24 hours, or at 8 ºC, if its shelf life is less than 24 hours.
- Frozen: equal to or lower than -18 ºC.

Therefore, in view of both regulations, the question arises whether a food made with eggs could be kept warm (≥63 ºC) or stored for more than 24 hours at ≤4 ºC, given that Royal Decree 1021/2022 (BOE, 2022) establishes a more restrictive limit (24 hours and ≤8 ºC) for products with raw eggs or egg products used according to their specific conditions.

2.2 Alerts and outbreaks related to the presence of *Salmonella* spp. in eggs and egg products

Globally, *Salmonella* spp. is recognised as one of the leading causes of foodborne illness. According to the World Health Organisation (WHO), non-typhoidal *Salmonella* infections represent a significant health burden on all continents, affecting both developed and developing countries. It is estimated that between 200 and 1 billion cases of *Salmonella* infection occur each year, resulting in approximately 93 million cases of gastroenteritis and about 155 000 deaths, of which about 85 % are linked to the consumption of contaminated food (He et al., 2023) (Lamichhane et al., 2024).

Foods of animal origin, especially eggs, poultry, pork and dairy products, continue to be the main vehicles of transmission, although fruits, vegetables and processed products have also been implicated. WHO and the Food and Agriculture Organisation of the United Nations (FAO), through the Global Foodborne Infections Network (GFN) initiative, highlight that control measures along the food chain, together with epidemiological surveillance, are essential to reduce the global incidence of salmonellosis.

In the context of the European Union, salmonellosis constitutes the second most frequent foodborne gastrointestinal infection in humans, after campylobacteriosis. According to the joint report of the European Food Safety Authority (EFSA) and the European Centre for Disease Prevention and Control (ECDC) (EFSA/ECDC, 2024), 77 486 confirmed cases of human salmonellosis were reported in the European Union in 2023, representing an increase of 16.9 % compared to 2022. Of these, 9210 cases (11.88 %) were attributed to a food origin, with 1726 hospitalisations (18.7 %) and 16 deaths (0.17 %) recorded.

Regarding foodborne outbreaks, 1115 outbreaks were detected in the European Union during 2023, of which 252 occurred in Spain (EFSA/ECDC, 2024). Most of them were associated with the consumption of contaminated eggs and egg products, followed by poultry and processed meat products.

Regarding the alerts, according to the Rapid Alert System for Food and Feed database (RASFF, 2025), between May 2020 and March 2025 there were 63 alerts for *Salmonella* in eggs and egg products in European countries. Of these, 17 were in egg products (pasteurised liquid egg, egg powder, egg white, egg yolk powder) and the rest in raw eggs.

It is important to note that cross-country differences in incidence and case reporting should be interpreted with caution as they may be due to variations in surveillance systems, case definition, sampling methods and health alert management. These methodological divergences underline the need to harmonise food risk control and communication systems at both the European and international levels.

3. *Salmonella* spp.

3.1 Classification of *Salmonella* spp. Aetiology and symptoms of salmonellosis

Salmonella are Gram-negative, bacillus-shaped, mobile, facultative and non-sporulated anaerobic bacteria belonging to the *Enterobacteriaceae* family (Billah and Rahman, 2024). The genus *Salmonella* is made up of two species: *Salmonella enterica* and *Salmonella bongori*. In turn, *S. enterica* is divided into six sub-species: *enterica* (I), *salamae* (II), *arizona* (IIIa), *diarizonae* (IIIb), *houtenae* (IV), and *indica* (VI) (Sivanandy et al., 2025), and includes a total of 2659 serotypes. Of these, *S. enterica* sub-species *enterica* causes 99 % of human and warm-blooded animal infections, and includes approximately 1586 serotypes (Park et al., 2009) (Issenhuth-Jeanjean et al., 2014). The current standard reference method for determining *Salmonella* serotypes is the White-Kauffmann-Le Minor (formerly Kauffmann-White) scheme, which is based on the use of specific antisera that, through agglutination reactions, allow the identification of different antigens: O (somatic: part of the lipopolysaccharides of the outer membrane), H (flagellar: proteins of the flagella) and Vi (capsular: polysaccharides of the capsule). Most *Salmonella* strains are diphasic and encode two H-antigen genes, phase 1 (H_1) and phase 2 (H_2), which are alternatively expressed within a single cell, but are simultaneously expressed in a population. The serogroup includes strains of *Salmonella* that share the same somatic antigen, while the serotype comprises strains that also share flagellar antigens. The Vi antigen, which confers greater virulence to the strains that possess it, may be present in only three *Salmonella* serovars: *S.* Typhi, *S.* Paratyphi C and *S.* Dublin (Moore et al., 2019) (Napoleoni et al., 2024).

Salmonella serotypes can be classified as typhoid and non-typhoid based on their ability to develop specific pathologies in humans. Typhoid serotypes are capable of infecting and colonising only a very small range of hosts, and include *S. enterica* serotype Typhi, *S. enterica* serotype Paratyphi A, B or C and *S. enterica* serotype Sendai, which only present as reservoirs to higher primates and humans, to which they are highly adapted (Johnson et al., 2018) (Ferrari et al., 2019) (Lamichhane et al., 2024).

Other specialised serotypes are associated with systemic diseases in other animal species, such as *S. enterica* serotype Gallinarum and *S. enterica* serotype Pullorum, with host specificity for birds (Shivaprasad, 2000). In contrast, generalist serotypes, including *S.* Enteritidis and *S.* Typhimurium (the two serotypes most frequently implicated in salmonellosis cases), can trigger infections in both humans and animals (Xu et al., 2021).

3.1.1 Salmonellosis

3.1.1.1 Significance

According to the WHO, *Salmonella* spp. is among 31 pathogens with the highest capacity to trigger intestinal or systemic diseases in humans among diarrhoeal or invasive agents (viruses, bacteria, protozoa, helminths and chemicals) and is the third leading cause of death among foodborne diseases (WHO, 2015). This pathogen is the second main causative agent of foodborne diseases in the European Union and the United States, preceded by *Campylobacter* spp. and norovirus, respectively (Ferrari et al., 2019).

3.1.1.2 Clinical picture

Salmonella is highly pathogenic and can cause life-threatening diseases due to its ability to penetrate, multiply and survive in human cells (Hansen-Wester et al., 2002) (Dieterich et al., 2018). There are three clinical manifestations of salmonellosis: gastroenteritis, sepsis and enteric fevers (typhoid and paratyphoid) (Crump et al., 2015).

Typhoid serotypes are responsible for disseminated non-specific infections, with symptoms including fever (39-40 ºC), headache, diarrhoea or constipation, loss of appetite, or bradycardia (Lamichhane et al., 2024), as well as neurological symptoms, leucopenia, sepsis, and immunological disorders (Billah and Rahman, 2024). Specifically, *S.* Typhi and *S.* Sendai infections are associated with high fever, diarrhoea, vomiting and headache, and death can occur in extreme cases. Infections with *S.* Paratyphi A, B or C have milder symptoms, such as diarrhoea, colic, fever and vomiting, and can sometimes cause sepsis.

On the other hand, non-typhoidal serotypes are responsible for gastroenteritis with varying degrees of severity or, rarely, bacteraemia (Andino and Hanning, 2015). While the symptoms of non-typhoidal salmonellosis are usually mild, their severity depends on the serotype involved and the immune status of the host. Compared to healthy adults, children and the elderly with weak immune systems are especially susceptible to infection (Kurtz et al., 2017). The main symptoms of non-typhoidal salmonellosis include fever, abdominal pain and diarrhoea. This is a usually self-limited process, which resolves in a few days without the need for treatment, with the patient recovering completely. However, approximately 5 % of individuals (primarily in children under 5 years of age, immuno-compromised individuals, and the elderly) may develop serious life-threatening bacteremia or invasive infections (e.g., meningitis) (Watler et al., 2024).

3.1.1.3 Epidemiology

Typhoid serotypes are highly host-specific and are transmitted from person to person via faecal-oral route (through consumption of contaminated water or food). Since these serotypes do not have animals as reservoirs, except for higher primates, their presence indicates contamination through inadequate hygiene when handling food and water (Newell et al., 2010).

For non-typhoidal serotypes, responsible for gastroenteritis, the most common reservoir is the intestinal tract of a wide range of domestic and wild animals, as well as various food matrices, which can serve as vehicles of transmission of *Salmonella* spp. to humans through faecal contamination. *Salmonella* is mainly present in food of animal origin, although the microorganism can also be present in vegetables or products of aquatic origin, both through contamination during production and through cross-contamination during processing (Carstens et al., 2019).

Transfer frequently occurs when these microorganisms are introduced into food preparation areas, with consequent proliferation in food due to inadequate storage temperatures, under-cooking or cross-contamination, as well as from direct contact with infected animals and humans.

3.2 Prevalence of *Salmonella* spp. in eggs and egg products

There are two possible routes of contamination of the content of intact eggs by *Salmonella*. In

horizontal transmission, the bacterium penetrates the shell; in vertical (transovaric) transmission, the egg's content is directly contaminated as a result of a *Salmonella* infection of the reproductive organs, before the eggs are covered by shell components (Howard et al., 2012). It is not yet clear which is the most significant contamination route of the egg content by *Salmonella*, although it has been indicated that, for *S.* Enteritidis, the transovaric contamination route seems to be more relevant than penetration through the shell (Cardoso et al., 2021).

The percentage of eggs that, at farm level, are internally contaminated with *Salmonella* is variable, but, in general, low (3 %) (EFSA, 2007). Some of the scarce data available in Spain report lower prevalences. Perales and Audicana (1989) observed a prevalence of 1.3 % in eggs associated with outbreaks of salmonellosis, while in eggs not associated with outbreaks the prevalence was 0.6 %. A previous report by AESAN (2007) indicated that the frequency of eggs externally contaminated with *Salmonella* at points of sale can sometimes be considerably higher (between 5 and 24 % of the eggs analysed in a study in the Autonomous Community of Madrid between 2003 and 2005 (Porrero et al., 2006)).

Salmonella levels in intact egg content are generally less than 10 CFU/egg, although eggs containing more than 10^5 CFU/g have also been found (Humphrey, 1994). The white of an egg is more frequently *Salmonella* positive than the yolk (Humphrey, 1994), suggesting that the oviduct is the site of colonisation (Cardoso et al., 2021). There is consensus that the growth in egg white, due to its antimicrobial compounds, is limited, even at room temperature (Kang et al., 2006). The study showed that egg albumin has a strong inhibitory capacity on *Salmonella*, limiting its growth thanks, in large part, to iron restriction and other antimicrobial barriers. In contrast, the yolk offers better conditions for growth, multiplication, and survival. In the yolk, storage at room temperature can result in a high concentration of *Salmonella* in a relatively short time; for example, generation times of 3.5 hours and 35 minutes have been obtained for *Salmonella* in egg yolks incubated at 15.5 ºC and 37 ºC, respectively (Bradshaw et al., 1990).

Data on the prevalence of *Salmonella* in eggs for consumption are scarce and variable, reflecting differences, for example, in the prevalence in animals intended for food production, as well as in the quality and coverage of surveillance systems (scheme, context, strategy or sampling unit and sample size). Despite the variability observed, it is generally recognised that the prevalence of *Salmonella* in eggs for retail sale is low in most developed countries (Cardoso et al., 2021). Thus, it is necessary to analyse a large number of eggs to detect *Salmonella* and obtain an accurate measurement of the percentage of contamination (Carrique-Mas and Davies, 2008). Ebel and Schlosser (2000) estimated that one in 20 000 eggs produced annually in the United States tests positive for *Salmonella* (0.005 %). In Europe, according to EFSA/ECDC data (2019), approximately 0.37 % of the eggs for retail consumption analysed (n= 6252) were contaminated with *Salmonella* (n= 23). It should be noted that these results were reported only by 13 Member States of the European Union, and that only Bulgaria, the Czech Republic, Italy, Poland, Portugal, Slovakia, Spain and Romania reported the presence of contaminated eggs (EFSA/ECDC, 2019). Prevalence data, levels and serotypes detected in consumer eggs from birds with different housing systems are shown in Table 1.

Table 1. Percentage of samples contaminated with *Salmonella* and serotypes found in different egg types and geographical areas

Geographical area / date of study	Egg type / prevalence / levels / serotypes detected	Reference
Korea / September to December 1998	Eggs (135 dozen) from 17 brands from retail outlets / 0 %	Chang (2000)
Japan / Spring and Autumn 2003	Liquid egg samples (134 from 4 processing plants; 200 g each) before pasteurisation / 72 %-100 % (depending on the processing plant) / from <1 CFU/g to 2.4 × 102 CFU/g / 25 serotypes detected (*S.* Enteritidis predominates)	Ohtsuka et al. (2005)
New Zealand / July 2005 to June 2006	Eggs from free-range hens (166 units -between 6 and 18 eggs- from retail establishments) / 0 % shell and 0 % content Eggs from hens raised on the ground (98 units -between 6 and 18 eggs- from retail establishments) / 0 % shell and 0 % content Eggs from caged hens (250 units -between 6 and 18 eggs- from retail establishments) / 3.6 % shell (9/250) and 0 % content / 8 samples with <5 MPN / egg and a sample with 44 MPN / egg / *S.* Infantis	Wilson (2007)
England / March 2005 to July 2006	Eggs from retail establishments from intensive production farms in different European countries / 1744 samples (one every 6 eggs) / 9.0 % (157/1744; total prevalence); 8.4 % (147/1744; shell); 0.6 % (10/1744; shell and content) / prevalence by country of origin: 25 % (Poland), 13.3 % (Spain), 0.6 % (France) and 0 % (Belgium, Germany, Portugal, Ireland and the Netherlands) / *S.* Enteritidis, *S.* Mbandaka, *S.* Rissen, *S.* Braenderup, *S.* Infantis, *S.* Panama, and *S.* Weltevreden	Little et al. (2007)
India / April 2006 to July 2007	Eggs from poultry farms / 3.84 % (10/260: 2 in shell, 7 in yolk, 1 in shell and yolk) / *S.* Typhimurium, *S.* Africana Eggs from wholesale establishments: 4 % (6/150: 3 in shell and 3 in yolk) / *S.* Typhimurium Eggs from retail establishments: 7.4 % (11/150: 7 in shell, 2 in yolk, 2 in shell and yolk) / *S.* Lagos, *S.* Rough, *S.* II	Singh et al. (2010)
Japan / August 2007 to January 2008	Eggs (2030 samples; 10 eggs per sample) from 220 retail establishments / 0.25 % (5/2030) shells) and 0 % (0/2030) / *S.* Enteritidis, *S.* Derby, *S.* Livingstone, *S.* Cerro	Sasaki et al. (2011)

Table 1. Percentage of samples contaminated with *Salmonella* and serotypes found in different egg types and geographical areas

Geographical area / date of study	Egg type / prevalence / levels / serotypes detected	Reference
United States / March 2012 to February 2013	Samples (1853) of liquid egg before pasteurisation taken in 48 approved establishments (726 in full content, 573 in whites, 544 in yolks) / 34.1 % (whole egg); 8.3 % (whites); 26.1 % (yolks) / *S.* Heidelberg, *S.* Braenderup, *S.* Enteritidis, *S.* Kentucky and *S.* Enteritidis	USDA/FSIS (2013)
Bangladesh / July to December 2013	Local market eggs / 120 shells and 120 contents / 45.8 % (55/120; shell); 13.3 % (16/120; content)	Mahmud et al. (2016)
China / August to October 2013 and March to November 2014	Eggs (814) from different origins: 304 eggs from caged chicken farms and 510 eggs from 18 retail establishments / 5.6 % (46/814; shell and content mix), 6.6 % (20/304) on farms and 5.1 % (26/510) on retail establishments / *S.* Typhimurium, *S.* Indiana, *S.* Thompson, *S.* Enteritidis, *S.* Norwich, *S.* Virchow, *S.* Derby, *S.* Senftenberg, *S.* Infantis, *S.* Albany, *S.* Blockley, *S.* Mbandaka, *S.* Braenderup	Li et al. (2020a)
Egypt / 2014	Eggs (200) from free-range hens / 0 % (shell) and 0 % (content)	Eid et al. (2015)
China / January to December 2016	Eggs from various sources / 5548 samples (each, at least 10 eggs from the same batch) / 0.5 % (27/5548; total prevalence); 0.3 % (19/5548; shell); 0.2 % (9/5548; content); *S.* Enteritidis, *S.* Typhimurium, *S.* Bonn, *S.* Choleraesuis, *S.* Infantis, *S.* Lomita, *S.* Narashino, *S.* Rissen, *S.* Stanley, *S.* Tarshyne, *S.* Typhi, *S.* Virchow	Li et al. (2020b)
Egypt / March to July 2017	Home-reared/poultry eggs (50) / 6.0 % (3/50; shell); 6.0 % (3/50; content) / *S.* Typhimurium, *S.* Enteritidis, *S.* Kentucky Intensive production eggs (200) / 2.5 % (5/200; shell); 2.5 % (5/200; content) / *S.* Typhimurium, *S.* Enteritidis, *S.* Kentucky, *S.* Infantis, *S.* Molade, *S.* Tamale, *S.* Labadi, *S.* Papuana	Elmonir et al. (2023)
Australia / October 2017 to June 2018	Free-range hen eggs / each sample is a container of 12 eggs / 6.4 % (6/93; total prevalence); 2.1 % (2/93; shell); 3.2 % (3/93; content); 1.1 % (1/93; shell and content) / *S.* Typhimurium, *S.* Infantis Eggs from hens raised on the ground / each sample is a container of 12 eggs / 17.9 % (7/39; total prevalence); 5.1 % (2/39; shell); 5.1 % (2/39; content); 7.7 % (3/39; shell and content) / *S.* Typhimurium, *S.* Infantis Eggs from caged hens / each sample is a container of 12 eggs / 14.7 % (10/68; total prevalence); 7.3 % (5/68; shell); 1.4 % (1/68; content); 5.9 % (4/68; shell and content) / *S.* Typhimurium, *S.* Infantis	Sodagari et al. (2019)

Table 1. Percentage of samples contaminated with *Salmonella* and serotypes found in different egg types and geographical areas

Geographical area / date of study	Egg type / prevalence / levels / serotypes detected	Reference
Portugal and Romania / December 2017 to August 2018	Eggs (200) from 56 farms in Portugal / 202 eggs from 94 farms in Romania / 0 % (0/200) in Portugal; 3 % (6/200) in Romania: 1 in shell and content, 3 in content and 2 in shell) / *S.* Typhimurium and *S.* Enteritidis	Ferreira et al. (2020)
Spain	Eggs purchased from Valencia markets / 5 organic farms (16 eggs); 5 free-range farms (10 eggs); 5 caged-hen farms (34 eggs) / 2.9 % (1/34; shell and content) eggs from caged hens	Fenollar et al. (2019)
Egypt	A total of 1050 eggs: 70 samples of 5 eggs (350 eggs) from each type of birds: bald hens, hens and legs; 90 samples of egg-based products (including 30 samples of mayonnaise, 30 of pastry cream and 30 of custard) / bald hens: 5.72 % (4/70)-8.58 % (6/70) in shell (depending on the culture medium used) and 1.43 % (1/70) in content; hens: 1.43 % (1/70) in shell and content; legs: 1.43 % (1/70)-4.29 % (3/70) in shell (depending on growing medium) and 1.43 % (1/70)-2.86 % (2/70) in content (depending on growing medium); egg-based products: 0 % (0/30; mayonnaise), 3.33 % (1/30)-6.66 % (2/30; pastry cream, depending on the culture medium used); 0 % (0/30; custard) / *S.* Typhimurium, *S.* Enteritidis, *S.* Anatum, *S.* Infantis, *S.* Kentucky, *S.* Shubra	El-Prince et al. (2019)
Ghana / October 2019 to August 2020	Eggs (2304; 384 samples of 6 eggs) from 30 retail establishments (unspecified method of rearing) / 5.47 % (21/384; shell or content); 1.43 % (5/384; shell and content); 4.95 % (19/384; shell); 1.82 % (7/384; content) / *S.* Ajiobo, *S.* Chester, *S.* Hader, *S.* Enteritidis, *S.* I 4:b:-	Archer et al. (2023)
Korea / 2022	Eggs from sorting and packaging establishments (E) analysed after washing; 16 800 60 E eggs (280 from each E) were analysed in groups of 20 eggs; 840 samples / establishments: 18.3 % (11/60; shell); 20.0 % (12/60; content); samples: 2.3 % (19/840) in shell and content / *S.* Infantis, *S.* Enteritidis, *S.* Agona, *S.* Newport, *S.* Bareilly, *S.* Montevideo, *S.* Senftenberg, *S.* Derby	Jung y Lee (2024)
Chile / May 2022 to January 2023	Eggs (426 samples; each sample 6 eggs; 2556 eggs tested): 240 from caged hens and 186 from alternative rearing systems (without cages) / 0 % (0/24) in caged hens and 1.1 % (2/186) in hens from alternative systems / *S.* Enteritidis	Solís et al. (2023)
China	Eggs from farms (138) and sorting centres (138); 100 egg products / 2.2 % (3/138) on farms; 0.7 % (1/138) on sorting centres; egg products / 34.0 % (34/100) on egg products / *S.* Enteritidis, *S.* Infantis, *S.* Mbandaka, *S.* Thompson, *S.* Corvallis	Meng et al. (2025)

3.3 Factors affecting survival of *Salmonella* spp. in eggs and egg products during storage

In relation to shelf life, certain intrinsic characteristics (such as pH, water activity or nutritional composition) and extrinsic characteristics (such as storage temperature, packaging atmosphere or applied technological treatments) can act as barriers that limit the survival and growth of microorganisms over the period of food storage. The application of a carefully selected and controlled combination of these factors delays or inhibits microbial growth, contributing decisively to the maintenance of the safety and quality of the product throughout its shelf life.

3.3.1 Reduction of prevalence and/or levels of *Salmonella* spp. in food

A variety of physical, chemical, and biological methods have been used in the food industry to reduce or eliminate *Salmonella* from food. Irradiation can cause colour changes (Kusmider et al., 2002), softening of tissues (Indiarto et al., 2023) or the formation of unpleasant odours (Chen et al., 2023). Some chemical disinfectants, such as chlorine and hypochlorite, can react with proteins and form carcinogens (Hawkins and Davies, 2001). The addition of organic and phytochemical acids is also frequent (Bajagai et al., 2020) (Nielsen and Knøchel, 2020). Elevated temperatures are not suitable for refrigerated raw foods such as eggs. The use of novel technologies instead of heat treatments has some advantages, especially when it comes to protecting the heat-sensitive nature of the egg without loss of its sensory and nutritional properties (Afraz et al., 2020). In this sense, pulsed electric fields (Liu et al., 2019), high-pressure processing (Naderi et al., 2017), ultrasound (Yüceer and Caner, 2020), microwaves (Li et al., 2018), radiofrequency (Yang et al., 2019), ultraviolet light (Holck et al., 2018) or cold plasma (Abdoli et al., 2024) have been used to inactivate microorganisms and at the same time preserve the quality of fresh egg-based products.

3.3.2 Probiotics and prebiotics

Antimicrobial alternatives to reduce the prevalence of contamination and the subsequent development of *Salmonella* in food include the use of prebiotics and probiotics. Prebiotics, non-digestible compounds that support the growth of healthy gut microbial populations, cause a reduction in gut pH, change the composition and activity of the microbiota, and prevent colonisation by enteric pathogens, including *Salmonella* (Donalson et al., 2007). On the other hand, supplementation with probiotics, live microorganisms that promote intestinal health, can also prevent the colonisation of the gastrointestinal tract by pathogens through competitive exclusion, the production of antimicrobial peptides (bacteriocins), the stimulation of the mucus production of goblet cells, the activation of the immune system, the reduction of the production of toxic metabolites (ammonia) and the improvement of the barrier function of the intestinal mucosa (Feye et al., 2016).

3.3.3 Elimination of *Salmonella* spp. in eggs and egg products

The poultry industry needs to have effective and cost-effective disinfection systems in place to ensure that consumers can easily access safe eggs and egg products. The first need is for effective environmental management of laying bird housing systems, which is essential to minimise opportunities

for introduction, transmission and persistence of *Salmonella* in eggs (EFSA/ECDC, 2022). On the farm, the most common method of decontaminating eggs is washing. However, this procedure is prohibited in the European Union, because it can damage the outer layer (cuticle) and increase the risk of contamination. Decontamination by gamma rays or electron beams is also prohibited (Muñoz et al., 2015) (EU, 2023).

3.3.4 Temperature

Temperature is one of the environmental factors that most influences bacterial growth. The best way, therefore, to prevent the multiplication of *Salmonella* and other pathogens is the strict control of the refrigeration of the eggs after collection (Syamily et al., 2023) (Baek et al., 2024). *Salmonella* is able to grow in a wide range of temperatures: between 5 and 47 ºC, with an optimal temperature between 35 and 42 ºC (D'Aoust, 1989). In eggs, the minimum growth temperature of *Salmonella* Enteritidis is around 6-8 ºC (Kim et al., 2018) (Kang et al., 2021), being slightly higher in the white than in the yolk or in whole liquid egg (Guillén et al., 2024). This minimum temperature, however, appears to depend on the initial dose of the pathogen (Guillén et al., 2024).

3.3.5 Food acidification

Raw egg-based sauces, such as mayonnaise and aioli, are often identified as sources of *Salmonella* during foodborne outbreaks. To inhibit the development of this pathogen in raw egg-based products, the use of organic acids such as the components of lemon juice or vinegar is recommended. As has been repeatedly demonstrated, the addition of acids contributes to reducing the development of *Salmonella* in mayonnaise, in various dressings and in lemon mousse (Keerthirathne et al., 2016) (Nielsen and Knøchel, 2020). What is common to all these indications on the use of acids to reduce *Salmonella* levels or inhibit its growth is that the pH of the final preparation should be 4.1-4.2 or lower. *Salmonella*, however, can develop acidity tolerance and survive under these conditions (Lock and Board, 1995) (Li et al., 2025). How the bacteria adapts depends on the temperature and is higher at room temperature than in refrigeration. In general, acidified products can be kept at room temperature for a maximum period of 72 hours (Lock and Board, 1995) (Keerthirathne et al., 2019) (McWhorter et al., 2020) (Nielsen and Knøchel, 2020) (Government of South Australia, 2022).

3.3.6 Other additives

3.3.6.1 Lysozyme

Lysozyme present in egg whites is an enzyme with high hydrolytic activity on the cell wall of Gram-positive bacteria (Alabdeh et al., 2011) (Legros et al., 2021), and may also have some activity against Gram-negative bacteria (Baron et al., 2016). The best-known activity of lysozyme is the degradation of the glycosidic bond (1,4-ß) between the N-acetylglucosamine and N-acetylmuramic acid residues of peptidoglycan. Loss of the wall ultimately leads to membrane rupture and cell death.

3.3.6.2 Antimicrobial proteins and peptides

In the egg, in addition to lysozyme, there are a variety of proteins and peptides with antimicrobial activity such as ovotransferrin, protease inhibitors, and vitamin-binding proteins (Alabdeh et al., 2011)

(Legros et al., 2021). Ovotransferrin is an egg white protein that belongs to the transferrin family and, like it, has an iron chelating activity (Legros et al., 2021), an essential nutrient for almost all bacterial species that infect humans (Cassat and Skaar, 2013). The antimicrobial activity of ovotransferrin against *Salmonella* has long been known (Baron et al., 1997). Although little is known about key factors in the egg such as alkalinity, high viscosity, ionic composition, possible synergistic action with other proteins, or the impact of storage and technological practices on ovotransferrin activity (Baron et al., 2020). Ovotransferrin is also capable of causing alterations in the plasma membrane, which provides a second mechanism that limits bacterial growth (Baron et al., 2020). Egg white may also contain peptides with antimicrobial activity that may act synergistically in protecting against pathogens (Cochet et al., 2021).

3.3.6.3 Other compounds

In recent years, the use of natural antimicrobials has been proposed, such as essential oils (Moosavy et al., 2008) (Laptev et al., 2021) (Osaili et al., 2021) or bacteriocins (Moosavi et al., 2008) (Hu et al., 2019) (Bermudez-Aguirre and Niemira, 2023), among others. Recently, it has also been verified that the addition at physiological levels of other nutrients, such as the amino acids arginine and cysteine, inhibits the growth of *Salmonella* in egg whites (Ben-Porat et al., 2024). The mechanism of action could involve modification of the chemical environment, interaction with the bacterial outer membrane, or modification of gene expression, resulting in an inappropriate state for the survival and development of *Salmonella* in eggs.

3.3.7 Use of bacteriophages

Many studies suggest that lytic bacteriophages may be effective in various food industry processes to control foodborne pathogens, including *Salmonella* (Grant et al., 2017) (He et al., 2024) (Sun et al., 2024), being promising candidates as antibacterial agents in the context of preserving fresh food at refrigeration temperatures (Sun et al., 2024).

In products containing eggs, the application of phages as an additional control measure could be especially useful in ready-to-eat preparations that do not receive sufficient heat treatment to eliminate *Salmonella* spp. This strategy is supported by recent regulatory developments at the European level. In June 2023, the European Parliament recognised the potential of bacteriophages in the fight against antimicrobial resistance and requested the European Commission to prioritise a regulatory framework for their registration as food additives and as veterinary medicinal products (PhageEU, 2025). However, the legal status of their use in the food industry is currently under review and specific evaluations are required to validate its efficacy and stability in these matrices.

A judgment of the Court of Justice of the European Union in 2019 concluded that the placing on the market of lithic phages in the Union market is subject to prior authorisation by the Commission both as an additive and as a decontaminant in order to be placed on the market (Europa Press, 2019).

3.3.8 Modified atmospheres

The effect of different modified-atmosphere packaging regimens on the growth and survival of

Salmonella spp. has been studied in various food matrices (minced meat, fresh lettuce, chicken fillet and shrimp) experimentally contaminated with the pathogen, but not in eggs or egg products (Sant'Ana et al., 2013) (Zhou et al., 2015) (Sukumaran et al., 2016) (Djordjević et al., 2018). The simplest modified atmosphere is vacuum, followed by those in which air is replaced totally or partially by other gases (usually CO_2 or N_2). In general, significant differences are observed between the *Salmonella* counts in the different foods analysed packaged in air, under vacuum or those packaged in modified atmospheres. The greatest development of *Salmonella* happens in unprotected food in the air, followed by food preserved under vacuum. In a good number of challenge trials, *Salmonella* is more inhibited the higher the concentration of CO_2 (Sant'Ana et al., 2013) (Djordjević et al., 2018). However, other studies report good growth of *Salmonella* in the presence of 100 % CO_2 or 100 N_2 (Nychas and Tassou, 1996) (Horev et al., 2012). Different methodologies may explain some of the discrepancies between studies, but there is no doubt that differences between strains can contribute to the variations between results. For better protection, modified atmospheres can be combined with other antimicrobial agents such as organic acids (Pelyuntha and Vongkamjan, 2023), essential oils (Zhou et al., 2013) (Nair et al., 2015) and other compounds (Michaelsen et al., 2006).

3.3.9 Curing egg yolk

Curing is a process that has traditionally been used to dehydrate foods such as meat, fish and vegetables. Dehydration inhibits microbial multiplication and prevents oxidative reactions of lipids and proteins that lead to off-flavours in foods (Pittia and Antonello, 2015). Recently, chefs are curing egg yolks using a mixture of salt and sugar and then heating it. The solutes gradually diffuse into the yolk and, as a result, it solidifies from the outside to the inside. Cured yolks add depth and complexity of flavour to a wide range of foods: salads, soups, pastas, and even meat (Adamant, 2019) (Pryles, 2020). The evolution of *Salmonella* through curing has recently been evaluated in contaminated yolks (Machado et al., 2020). These authors inoculated the yolks with the pathogen (8.4 log CFU/g), covered with a sugar mixture and stored at 4.5 ºC for 2, 24, 72 and 144 hours. Subsequently, they were heat-treated at 62 ºC for 30 minutes in a water bath or at 80 ºC in an oven for 3 hours. With the mildest healing and thermal treatment (2 hours; 62 ºC for 30 minutes), *Salmonella* populations were reduced by 5.6 log CFU/g (Machado et al., 2020).

4. Predictive microbiology models available for *Salmonella* spp. in egg and egg products

In order to assess the risk posed by the proliferation of *Salmonella* in prepared egg-based foods and egg products, predictive microbiology models constitute a key tool for estimating the behaviour of the pathogen under different storage conditions.

In the literature there are predictive models applicable to evaluating the growth of different *Salmonella* serotypes in eggs and egg products, both raw and pasteurised. Table 2 shows a summary of the main publications where predictive growth models are developed, taking into account storage temperature as the main factor in all of them. These models allow the main growth parameters to be estimated, that is, maximum growth rate (μ_{max}, log CFU/g/h), latency phase (λ, hours), or maximum population density (γ_{max}, log CFU/g). Most published studies based on predictive

models consider storage temperature to be a fundamental factor.

Table 2. Summary of the main predictive microbiology models for estimating *Salmonella* spp. growth in eggs and egg products

Food matrix	Serotypes	Factors	Models	Reference
Egg white (raw and pasteurised)	*S.* Enteritidis *S.* Typhimurium *S.* Montevideo *S.* Kentucky (6-strain cocktail)	T [a] (5-37 ºC)	Baranyi Davey Square-root	Kang et al. (2021)
Unpasteurised liquid egg (white and yolk)	*S.* Enteritidis *S.* Typhimurium *S.* Gallinarum (5-strain cocktail)	T (5-40 ºC)	Baranyi Davey Square-root	Kim et al. (2018)
Unpasteurised egg yolk	*S.* Enteritidis (5-strain cocktail)	T (7-43 ºC)	Baranyi Modified square-root	Gumudavelli et al. (2007)
Scrambled eggs	*S.* Blockley *S.* Enteritidis PT 4 *S.* Enteritidis PT 13 *S.* Heidelberg *S.* Typhimurium (5-strain cocktail)	T (10-47 ºC)	Baranyi Square-root	Li et al. (2017)
Unpasteurised liquid egg (white and yolk)	*S.* Blockley *S.* Enteritidis PT 4 *S.* Enteritidis PT 13 *S.* Heidelberg *S.* Typhimurium (5-strain cocktail)	T (5-47 ºC)	Baranyi Extended square root	Singh et al. (2011)
Unpasteurised liquid egg (white and yolk)	*S.* Enteritidis *S.* Typhimurium *S.* Montevideo *S.* Kentucky (6-strain cocktail)	T (5-37 ºC)	Baranyi Polinomial Davey Square-root	Park et al. (2020)
Liquid egg (pasteurised and unpasteurised)	*S.* Enteritidis (4-strain cocktail)	T (8-36 ºC)	Modified logistics Square-root	Sakha and Fujikawa (2013)
Whole egg, albumen, yolk (10 % sucrose and 10 % salt)	*S.* Typhimurium (2-strain cocktail)	T (4-42 ºC)	Baranyi	Musgrove et al. (2009) [b]

[a] Temperature. [b] Model implemented in Combase (2025).

In general, in the case of raw eggs, the yolk favours the growth of *Salmonella* spp., while egg white shows a bacteriostatic effect, probably due to its high content of lysozyme and alkaline pH. In addition, the growth of the pathogen is observed at temperatures equal to or higher than 10 ºC. In this regard, Park et al. (2020) developed a model under non-isothermal conditions for raw egg yolk obtaining values of μ_{max}= 0.034 log CFU/mL/h at 10 ºC, increasing with storage temperature until reaching values of 1000 log CFU/ml/h at 37 ºC. Unpasteurised liquid egg products, such as liquid whole egg, yolk, and white, primary and secondary models were developed with growth evident in yolk and whole egg at temperatures >10 ºC, but absent in egg white (Kim et al., 2018). In these cases, the primary Baranyi function was used, while Davey's equations and/or quadratic models were used as secondary models.

Likewise, the growth of *Salmonella* has been modelled using quadratic and Davey models, with results that show a greater proliferation under thermal abuse conditions between 20 ºC and 30 ºC

in pasteurised products compared to raw ones, highlighting the importance of post-pasteurisation storage conditions (Kang et al., 2021). On the other hand, the dynamic model developed by Singh et al. (2011) for whole liquid egg adjusted to pH 7.8 and subjected to sinusoidal temperature profiles showed accurate predictions under non-isothermal conditions (RMSE 0.23-0.28 log CFU/ml), underlining its usefulness for assessing risks in cooling-failure scenarios.

In raw eggs, it has been observed that the latency phase is longer and the maximum specific growth rate is lower compared to pasteurised products, especially when the initial inoculum is low (Guillén et al., 2021). This is partly due to the activity of antimicrobial proteins such as ovotransferrin, which takes the iron needed for bacterial growth, limiting *Salmonella*'s ability to adapt to the environment. In contrast, the heat treatment applied in pasteurisation partially inactivates these proteins, thereby increasing the bio-availability of iron and allowing a higher growth rate even from low initial concentrations (Guillén and Cebrián, 2022). It has also been shown that, in unpasteurised liquid whole eggs, the minimum growth temperature of *S.* Enteritidis varies between 7.2 ºC and 7.9 ºC, while in pasteurised products these temperatures may decrease due to the effect of heat treatment on the matrix (Guillén et al., 2024).

As for the effect of the addition of salt or sugar in the formulation of egg products (e.g., pastry or stabilised yolks), it has been shown to significantly affect the water activity and osmolarity of the medium. Several studies have shown that, although both salt and sugar tend to inhibit bacterial growth by reducing the availability of free water, their effect may be insufficient to completely prevent the proliferation of *Salmonella* under certain conditions. Palumbo et al. (1995) analysed the behaviour of *Salmonella* spp. in liquid egg yolks with different concentrations of salt (10 % and 20 %) and sugar (5 % and 10 %) at temperatures between 61.1 ºC and 66.7 ºC. They found that, despite the increase in thermal resistance induced by these solutes, growth prior to pasteurisation was still possible under conditions of temperature abuse, especially if inoculation was high and refrigeration poor. A risk assessment report carried out by the FSIS (Food Safety Inspection Service) (Latimer et al., 2008) revealed that yolks pasteurised with 10 % sugar showed no association with cases of salmonellosis in population models, suggesting that, after effective pasteurisation, the possibility of growth is zero or negligible. However, in formulations with 10 % salt, although the risk was very low (11 estimated annual cases in the United States), the possibility of bacterial growth was maintained if refrigeration conditions were not strictly met. This is attributed to the fact that salt, while reducing water activity, can also confer osmotic protection to bacteria, increasing their resistance to thermal and osmotic stress.

However, results may differ depending on the *Salmonella* serotype evaluated or the environmental conditions of the food matrix itself. Musgrove et al. (2009) evaluated the behaviour of multi-drug-resistant *S.* Typhimurium DT104 in four liquid egg products: whole egg, albumen, sugary yolks, and salty yolks incubated between 4 and 42 ºC for 384 hours. The authors observed high growth (10^8-10^9 CFU/ml) in a whole egg and sugared yolk (10 % sugar) at temperatures ≥10 ºC, reaching maximum density at temperatures between 37 and 42 ºC. However, in albumen no growth above 1 log CFU/ml was observed, similar to in salty yolks (10 % NaCl), where reductions of up to 3 log CFU/ml were observed due to reduced water activity.

Therefore, it follows that storage temperatures of eggs and egg products above 10 ºC would be compatible with the growth of *Salmonella* in those matrices that tolerate the growth of the pathogen. According to the published information, the storage conditions of prepared meals based on eggs and egg products considered in Royal Decree 1021/2022 (BOE, 2022) would not allow the proliferation of *Salmonella*.

4.1 Methodology carried out for the implementation of predictive microbiology models for the validation of egg and egg product storage conditions

Despite the existence of validated predictive models in the scientific literature, a common limitation is that these models tend to be developed for very specific conditions (type of matrix, fixed temperature, specific formulations, etc.), which hinders their widespread application in real environments with operational variability. This high specificity limits their practical utility for risk assessment in different catering and retail scenarios. For this reason, it has been considered more appropriate to validate a model previously developed and applicable to *Salmonella* in matrices with eggs, which allows its general use in several situations. This approach seeks to ensure a robust scientific basis, but one that is also operational, to support more flexible regulatory decisions adapted to the reality of the sector.

Therefore, this report has proceeded to calibrate and validate a single published model for *Salmonella* that can be used in all the scenarios proposed in this report. This facilitates a more reliable comparison of the results obtained, since the conditions used for the development of the different published models can differ widely, which could lead to errors in the interpretation of the estimates.

4.1.1 Application of a probability model

To study the probability of growth of the pathogen under the different conditions of the products under study, the model of Pin et al. (2011), whose mathematical expression is represented in Equation 1, was selected.

$$\text{Logit}(p) = b0 + b1 \cdot (T - T_{min}) + b2 \cdot (pH - pH_{min}) + b3 \cdot (a_w - a_{wmin}) \quad \textbf{Equation 1}$$

with b0, b1, b2 and b3 being the coefficients obtained by regression and T_{min}, pH_{min} and a_{wmin}, parameters with biological interpretation also obtained by regression, and whose values were 3.01, 3.35 and 0.92, respectively. The other coefficients are included in Table 3.

Table 3. Values of the regression parameters used in Equation 1 to estimate the probability of growth of each pathogen

Parameter	Value
b0	-2.3
b1	2.27
b2	2.19
b3	1.83

The model was developed in broth, but validated for different types of products, and particularly meat products. Among all of them, studies of egg products are not included. However, because the model is based on observations made in a culture medium, the estimates are considered conservative. In other words, in food, or a solid matrix, the probability would be markedly less than that observed in an aqueous medium or broth. Therefore, it is proposed as a safe initial approach in the assessment of the possible growth of the pathogen under the conditions under study. According to the usual standards for pathogens to determine unlikely or assumable growth, the probability values should be below 0.01 (<1 %). Thus, this was the threshold used to determine under which conditions *Salmonella* could result in a possible growth of the pathogen.

4.1.2 Validation and calibration of a growth model for *Salmonella* in egg products

In order to consider, in the predictions, the different typologies and characteristics of egg products, a validation and calibration process of an existing model was carried out, applying pathogen kinetic values obtained from the ComBase database (Baranyi and Tamplin, 2004). The predictive model used corresponded to the model developed by Pin et al. (2011) for *Salmonella* growth. This model is based on the equation proposed by Presser et al. (1997), which describes the square root of the maximum specific growth rate (μ_{max}) as a function of temperature (T), water activity (a_w), and pH. The inclusion of these variables in the model would enable describing the growth of *Salmonella* in products with different physico-chemical characteristics (Equation 2).

$$\mu_{max} = [b \cdot f \cdot (T - T_{min}) \cdot \sqrt{(a_w - a_{wmin})} \cdot \sqrt{(1 - 10^{\wedge} (pH_{min} - pH))}]^2 \quad \textbf{Equation 2}$$

where:

μ_{max}: maximum specific growth rate (1/h)
b: empirical scale factor
f: calibration factor (dimensionless)
T: temperature (ºC)
T_{min}: minimum temperature for growth (ºC)
a_w: water activity
a_{wmin}: minimum water activity for growth
pH: ambient pH
pH_{min}: minimum pH for growth

The original parameter values proposed by Pin et al. (2011), derived from data in broth, were:

b= 0.209
T_{min} = 4.27 ºC
a_{wmin} = 0.947
pH_{min} = 3.69

This model allows the prediction of both the growth and the inactivation of *Salmonella* under dynamic conditions of temperature, pH and a_w, which is fundamental to reflect the real variations to which these products are subjected throughout their shelf life. In addition, one of its main advantages is that it has been built from a large set of experimental data and using various strains and serotypes of *Salmonella*, which has motivated its selection.

4.1.3 Validation with egg product data

The model was validated using experimental data on *Salmonella* growth in egg products, extracted from the ComBase database (2025). Data corresponding to temperatures ≤25 ºC were selected.

For record collection, the following search terms were entered: organism (*Salmonella*); category (eggs and egg products); temperature range (0-50 ºC). In total, 413 records were collected for the selected matrices, classifying them into pasteurised or unpasteurised products. For each record, the value of temperature, pH, a_w, serotypes, and, where appropriate, humidity conditions, sugars and % NaCl have been collected. The primary Baranyi model was then adjusted to the growth data for each record, obtaining the maximum growth rate value (μ_{max}, log CFU/g).

Lastly, the μ_{max} data were filtered to eliminate those records that were anomalous or that did not have a proportional correlation with the storage temperature. Finally, for model validation, 232 *Salmonella* growth data were used (Annex I).

The types of products for which growth rates were obtained included whole egg, or parts thereof, raw or heat-treated, yolk or albumen treated with sugary heat, desserts such as pastry cream and custards, and other types of products such as quiche (Table 4). Within the collected matrices, the most representative products are the liquid whole egg and the egg yolk. Approximately 56 % of the products were subjected to heat treatment (pasteurisation), which allows a comparison of the differences in microbial behaviour between treated and untreated products to be made.

Table 4. Types of egg-based products collected in ComBase (2025) and their correspondence with the categories of prepared foods analysed in this report

Types	Equivalence [a]		
	1	2	3
Albumen	x	x	x
Eggshell	x		x
Pasteurised egg white [b]		x	
Egg-based food [b]	x		
Steamed egg		x	
Whole egg (albumen surface) [b]	x		x
Whole egg (yolk surface)	x		x
Whole egg powder [b]		x	
Liquid whole egg	x	x	x
Scrambled egg	x	x	
Pastry cream		x	

Table 4. Types of egg-based products collected in ComBase (2025) and their correspondence with the categories of prepared foods analysed in this report

Types	Equivalence [a]		
	1	2	3
Quiche	x		
Sugared yolk		x	
Egg white	x		x
Liquid yolk with salt [b]	x	x	x

[a] 1: Meals prepared from raw egg subjected to a treatment of 70 ºC for 2 minutes or equivalent. 2: Meals prepared from pasteurised egg products. 3: Meals prepared from raw eggs for immediate consumption. [b] Typologies for which no *Salmonella* growth data have been found in ComBase (2025).

Different groupings were made, separating heat-treated and untreated egg products (raw egg), and excluding, from the first group, sugared egg products (custard, sugared albumen, etc.), which were analysed separately. The data covered a wide range of conditions for a_w and pH, but also included other factors such as salt or sugar content (Table 5). As for environmental conditions, the data contemplate a range of temperature conditions between 7.9 and 45 ºC, ranging from refrigeration conditions to thermal abuse scenarios. The pH recorded ranges from 6.0 to 9.0; while the values of a_w were only reflected for a total of 83 records, ranging around 0.98.

The values of μ_{max} were between 0.0019 and 1.02 log CFU/g/h, mainly depending on the storage temperature conditions. Finally, it should be noted that the data include a variety of *Salmonella* serotypes, mainly *S.* Enteritidis and *S.* Typhimurium.

Table 5. Range and average of product and temperature factors extracted from the Combase database (2025) used in the validation and calibration of the model by Pin et al. (2011)

Factor	Minimum	Maximum	Average
Water activity (a_w)	0.880	0.997	0.987
pH	6.0	9.0	7.1
NaCl (%)	0.3	3.0	1.2
Sugars (%)	9	10	9.8
Temperature (ºC)	8	25	18

Validation was performed using the bias factor (B_f) and the accuracy factor (A_f), as defined by Ross (1996).

The model showed a clear tendency to overestimate the growth rates observed in both types of products, as can be seen in Figures 1A and 1C. The results for the validation indices were B_f>2 and A_f>2.5; being outside the acceptable limits ($1.0 \leq B_f \leq 1.25$; $1.0 \leq A_f \leq 1.25$), indicating a low predictive performance in this type of food.

To improve the predictive capacity of the model, a calibration step was carried out, using as a calibration set the same data extracted from ComBase (2025). Calibration was performed by applying an adjustment factor (f) that minimised bias, directly adjusting the original equation.

The adjustment factor for heat-treated egg products and raw egg did not vary, being the same in both types of products (f= 0.6895). The application of *f* in raw egg resulted in a substantial improvement of its predictive capacity, with values within the acceptable ranges, i.e., B_f= 1.00 and A_f= 1.52. On the other hand, for egg products subjected to heat treatment, the result was less satisfactory, resulting in an A_f= 2.03. Therefore, in this case, considering that f was the same for both products, a joint validation and calibration was carried out, where A_f= 1.90 was obtained.

Validation and calibration for sugary egg products resulted in an improvement of the validation indices, with B_f=1.00 and A_f=1.53, these values corresponding to the application of f=0.8611 (Figure 1).

The calibration made it possible to adapt the model of Pin et al. (2011), initially formulated under laboratory conditions, to real conditions in food matrices considering two types of egg products, the non-sugared, which include those treated with heat or raw, and those sugared, heat-treated. Therefore, to estimate the growth of *Salmonella*, the appropriate adjustment factor was selected according to the product's belonging to one of these two categories.

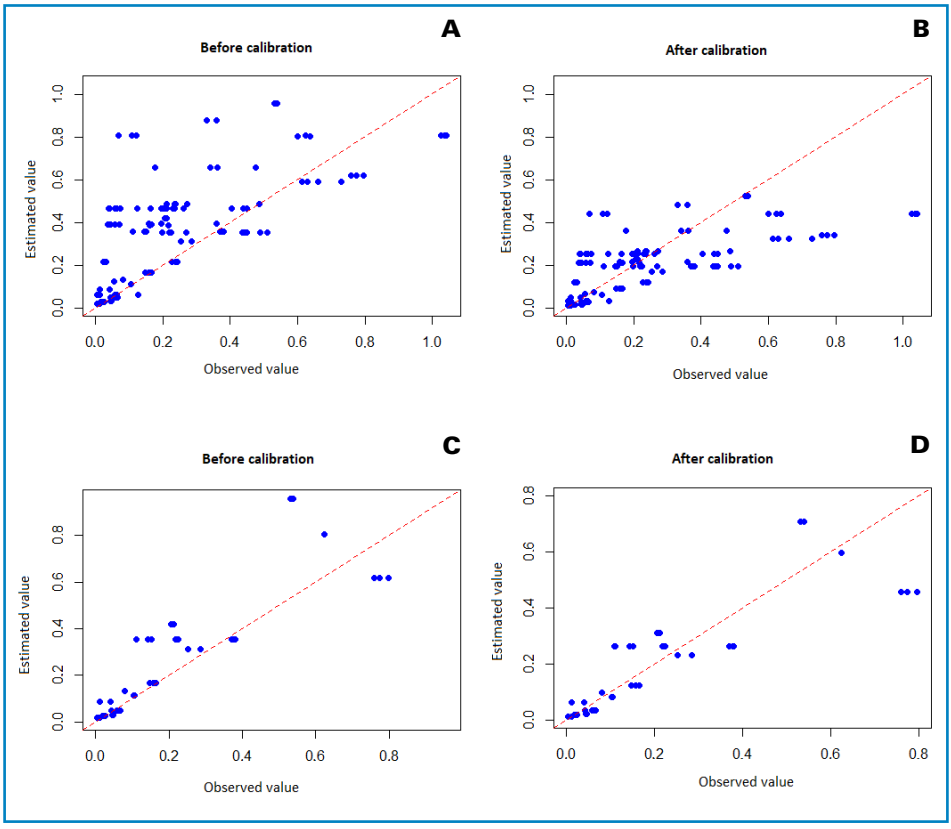


Figure 1. Validation charts of the specific maximum growth rate of *Salmonella* in non-sugared (A and B) and sugared (C and D) egg products, before and after their calibration. The dotted line is the line of equivalence of the observations and predictions, that is, a perfect match, while the points are the graphical representation of the validation data obtained from the Combase database (2025) and the corresponding predictions.

5. Shelf life: estimation of *Salmonella* growth in egg products and storage scenarios

In the context of food production, shelf life refers to the period of time after manufacture of the food in which the product is considered safe for consumption or continues to have the quality intended by the manufacturer. Establishing the shelf life of a food is the direct responsibility of the food operator who must justify it through relevant data and studies. Currently, different approaches are recognised that, either alone or in combination with each other, are used to determine the shelf life. On the one hand, shelf life studies under actual storage conditions are a widely accepted approach because they directly reflect the behaviour of food under actual conditions, although they require time and considerable resources. Another way is the challenge tests, in which the food is deliberately inoculated with the most relevant pathogenic microorganism and its behaviour during storage is evaluated. These tests allow determining if the food can withstand the presence of certain pathogenic microorganisms without them growing to dangerous levels during their shelf life. Another strategy is to rely on historical or bibliographic data that allow the operator to initially establish the shelf life, however, this method requires an actual validation on the food. And, lastly, there is the use of predictive models, which allow estimating the microbiological behaviour (growth, survival or inactivation) under different conditions of temperature, pH, water activity, etc. These models are useful for estimating life scenarios, optimising experimental tests or validating changes in formulations, provided that they are used within their range of validity and are combined with relevant own or bibliographic data.

In this report, the methodology described in the previous section for *Salmonella* spp. has been used to estimate the shelf life of different types of meals prepared with egg and egg products. To this end, different storage scenarios have been established and different foods representing different types of prepared egg-based meals and egg products have been chosen as a model.

5.1 Characteristics of selected egg products and definition of storage scenarios

The selected products were defined based on their most relevant physico-chemical characteristics. The average and maximum values were determined for them, based on scientific literature. In some cases, where information was limited or non-existent, the value was assumed using expert judgment (e.g., cured egg pH). These data are presented in Table 6.

Table 6. Average and maximum values of water activity (a_w) and pH for different types of egg products, based on data collected from scientific publications

Product	a_{wmin}	a_{wmax}	Average a_w	pH_{min}	pH_{max}	Average pH	Reference
Tiramisu	0.91	0.99	0.97	5.5	6.5	6.1	Lee et al. (2021) Giacometti et al. (2022) Franciosa et al. (1999)
Omelette	0.97	0.99	0.99	6.5	7.2	6.9	Baños et al. (2012) Valero et al. (2014)

Table 6. Average and maximum values of water activity (a_w) and pH for different types of egg products, based on data collected from scientific publications

Product	a_{wmin}	a_{wmax}	Average a_w	pH_{min}	pH_{max}	Average pH	Reference
Raw egg-based tartare	0.97	0.99	0.98	5.3	5.8	5.5	Tirloni et al. (2024)
Cured egg [a]	0.76	0.94	0.84	6.0	6.3	6.1	Lopes et al. (2020)

[a] Assumed pH equivalent to unprocessed egg yolk.

The assessment of growth, and its extension, was studied using different storage or shelf life scenarios, in accordance with the issues raised. In these, variations in cooling temperature and storage time are considered representative. The scenarios designed are shown in Table 7. The assumed starting concentration of *Salmonella* corresponded to 1 CFU/g, and the maximum possible population density was set to 10^7 CFU/g in all cases.

Table 7. Time and temperature scenarios used in the study of *Salmonella* growth in egg products

Scenario	Temperature (ºC)	Time (hours)
1	4	0-72
2	8	24
3	8 (with abuse 20, 3 hours)	24
4	8 (with abuse 12, 3 hours)	24
5	12	24

The scenarios evaluated reproduce the storage conditions established in Royal Decree 1021/2022 (BOE 2022), also incorporating situations of thermal abuse (for example, prolonged opening of cold rooms), in order to estimate the potential impact on the growth of *Salmonella* spp. in meals prepared from eggs and egg products.

5.2 Estimates of the behaviour of *Salmonella* spp. in the different categories of eggs and egg products and storage scenarios

The estimates provided by the probability model for storage at 4 and 8 ºC are shown in Table 8.

In all cases, the omelette is identified as the matrix with the highest risk of growth of *Salmonella spp.*, followed by tiramisu and, thirdly, tartare made with raw egg. In the case of the cured egg, the low values of a_w prevent the model from estimating an appreciable growth probability at either of the two temperatures evaluated, considering the average values of pH and a_w. Only storage at 8 ºC, combined with extreme values of both factors, could imply a risk of proliferation of the pathogen in this matrix.

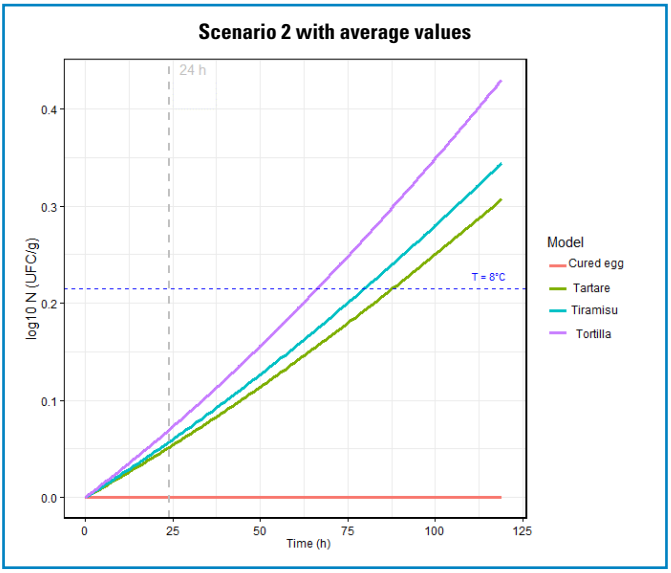
Table 8. Predictions of *Salmonella* growth probability (p) obtained by the Pin et al. (2011) model for combinations of pH and a_w characteristics of the egg products under study using average and maximum values of pH and a_w

Product	Temperature (ºC) [a]	p (mean pH and a_w)	p (pH and a_w maximums)
Tiramisu	4	0.0067	**0.0166** [b]
Omelette	4	**0.0215**	**0.0256**
Raw egg-based tartare	4	0.0055	0.0096
Cured egg	4	NA [c]	0.0014
Tiramisu	8	**0.1280**	**0.2680**
Omelette	8	**0.3223**	**0.3623**
Raw egg-based tartare	8	**0.1068**	**0.1743**
Cured egg	8	NA	**0.0310**

[a] Predictions at the lowest temperature are made, rather than at 4 ºC, at 4.3 ºC, which is within the application domain of the model of Pin et al. (2011), which defines T_{min}=4.27. [b] Values in bold indicate p>0.01, being associated with a possible growth of *Salmonella* under the conditions applied. [c] NA: combinations outside the biokinetic range of *Salmonella*.

As for the estimated growth of *Salmonella* spp., the model predictions for scenario 2 (8 ºC, 24 hours) are shown in Figure 2.

From the average values of pH and a_w, it is observed that omelette, tiramisu and tartare were the categories with the highest expected growth of *Salmonella spp.*, although in all cases this increase was less than 0.1 log CFU/g. The physico-chemical conditions of the cured egg prevented the development of the pathogen in this scenario. Nonetheless, when considering the maximum pH and a_w values, the model estimated slightly higher growth for tiramisu, reaching approximately 0.1 log CFU/g after 24 hours of storage. Omelette and tartare showed similar estimates, with a reduced increase, while, again, in the cured egg, no growth of the microorganism was estimated.



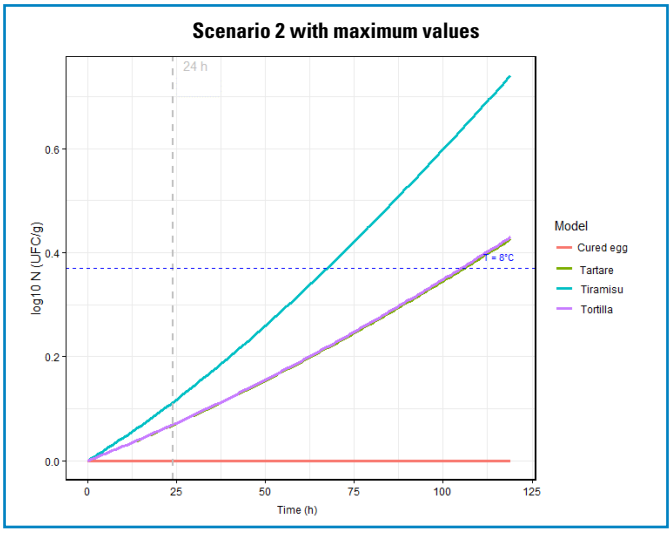
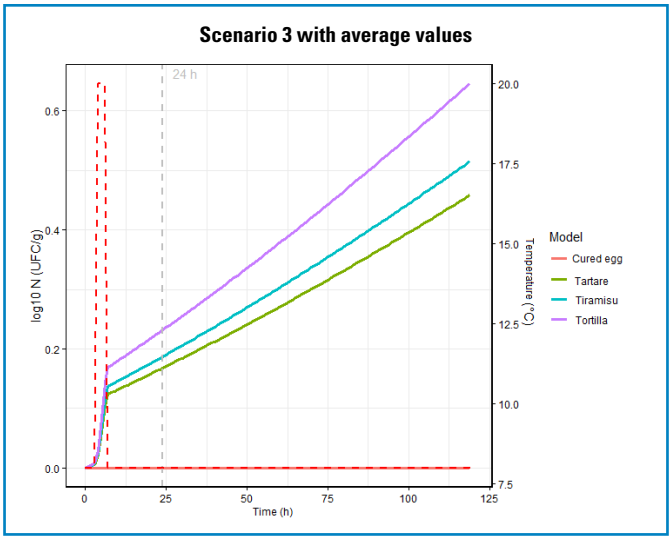


Figure 2. Estimates of *Salmonella* spp. growth in scenario 2 (8 ºC, 24 hours) provided by the calibrated model of Pin et al. (2011) for the selected egg and egg product categories using average and maximum pH values and a_w.

Scenario 3 contemplates a situation of thermal abuse, consisting of storage at 20 ºC for 3 hours (Figure 3). With the average pH and a_w values, the model again estimates a greater growth of *Salmonella* spp. in the omelette and tiramisu, followed by the tartare, with increases of around 0.2 log CFU/g at 24 hours of storage. When considering the maximum pH and a_w values for each food category, the model predictions point to growth close to 0.4 log CFU/g in tiramisu, while in tartare and omelette the estimates are noticeably lower. In the case of the cured egg, the predictions do not indicate growth of the pathogen under these conditions.



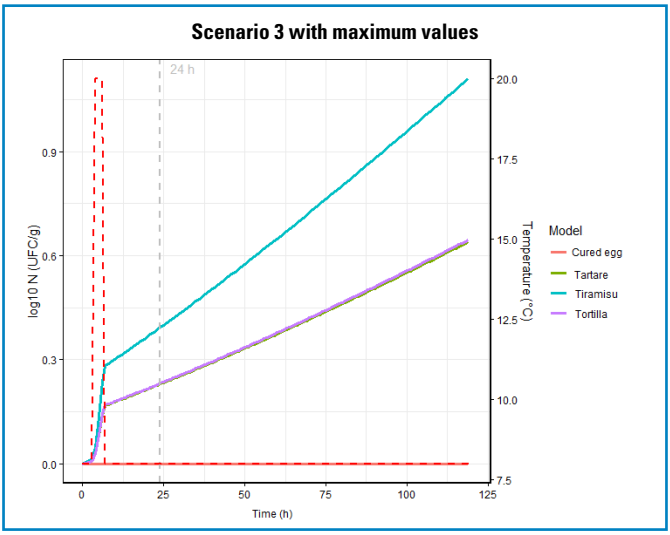
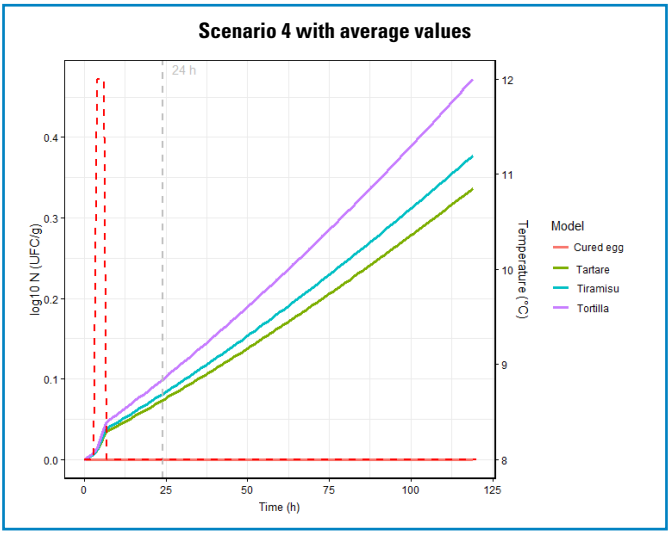


Figure 3. Estimates of *Salmonella* spp. growth in scenario 3 (8 ºC, 24 hours with abuse at 20 ºC for 3 hours) provided by the calibrated model of Pin et al. (2011) for the egg and egg product categories selected using average and maximum pH values and a_w.

For scenario 4, the growth of *Salmonella* spp. was simulated at 8 ºC for 24 hours, taking into account an abuse of temperature at 12 ºC for 3 hours (Figure 4). The model's predictions are in line with those described for scenario 3. Taking into account the average values of pH and a_w, again the omelette corresponds to the highest risk category, followed by tiramisu and tartare, although in the three matrices, the estimated growth was equal to or less than 0.1 log CFU/g. However, growth almost doubles if the maximum pH and a_w values are taken into account in the case of tiramisu. Again, the cured egg does not show growth of the pathogen.



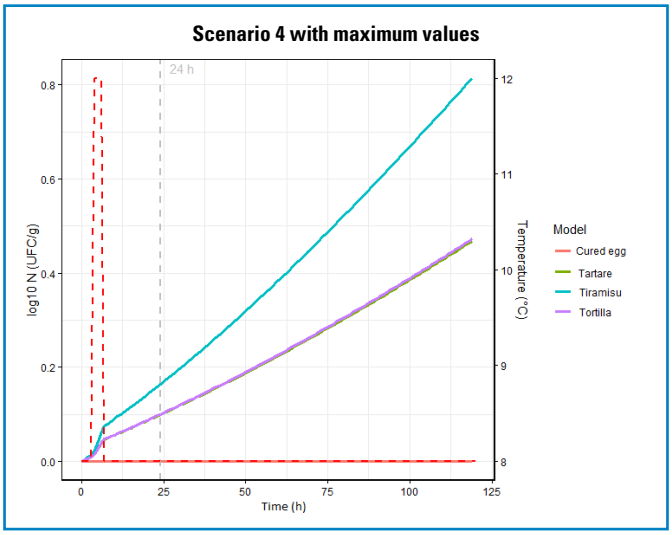


Figure 4. Estimates of *Salmonella* spp. growth in scenario 3 (8 ºC, 24 hours with abuse at 12 ºC for 3 hours) provided by the calibrated model of Pin et al. (2011) for the egg and egg product categories selected using average and maximum pH values and a_w.

Finally, scenario 5 represented the worst case conditions, with storage at 12 ºC for 24 hours. As can be seen in Figure 5, in the case of the omelette, the increase in *Salmonella* spp. at 24 hours of storage was close to 0.5 log CFU/g followed by tiramisu and tartare, with values around 0.3 log CFU/g. Neither did the model estimate growth for the case of the cured egg.

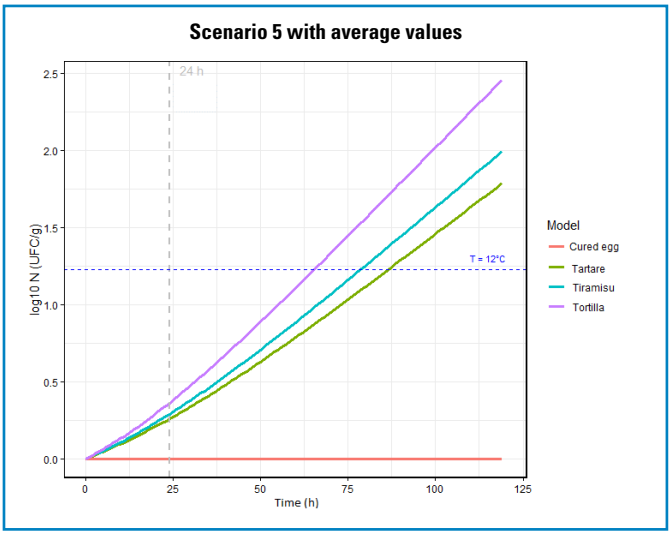


Figure 5. Estimates of *Salmonella* spp. growth in scenario 5 (12 ºC, 24 hours) provided by the calibrated model of Pin et al. (2011) for the selected egg and egg product categories using average and maximum pH values and a_w.

When the egg is used raw or undercooked, its initial microbiological quality decisively conditions the estimation of the safe shelf life of the final product intended for the consumer. In this regard, the formulation of ingredients may inhibit or limit the growth of *Salmonella* spp. in these matrices. McWhorter et al. (2020) evaluated how different formulation factors affect the survival of *S.* Typhimurium in sauces made with raw eggs, such as mayonnaise and aioli. Acidification was found to be a key factor, as pH≤4.2 markedly limits bacterial viability, and pH≤3.8 completely inhibits growth in less than 4 hours regardless of temperature. Whole egg sauces tend to have a higher pH and allow for longer survival than those made with yolk alone. There was no meaningful difference between vinegar and lemon juice as acidifying agents. In commercial sauces, the more acidic ones (pH 3.1-3.6) completely inhibited the pathogen, while the slightly higher pH ones kept *Salmonella* viable for longer, especially at 5 ºC. A non-acidified sauce (pH 5.4) allowed its persistence during the entire experiment at 5 and 25 ºC. The study concludes that raw egg-based sauces must be acidified and kept at room temperature for at least 4 hours before consumption to drastically reduce the cultivable form of *Salmonella*, warning that the use of whole eggs can attenuate the protective effect of acidification (McWhorter et al., 2020).

In relation to the storage of eggs and egg products, the microbiological risk will depend decisively on the hygienic conditions and handling practices during the preparation of prepared meals, including storage times and temperatures (EFSA, 2014).

Therefore, ensuring food safety begins with the acquisition of safe ingredients, from reliable suppliers, and their correct storage. Various international health authorities such as EFSA, FSANZ (Food Standards Australia New Zealand), FDA (Food and Drug Administration), FSAI (Food Safety Authority of Ireland) and USDA-FSIS (U.*S.* Department of Agriculture-Food Safety and Inspection Service) agree on a number of key recommendations to minimise the risk of *Salmonella* in products made with raw or lightly cooked eggs:

1. Replacing raw eggs: use safer alternatives in preparations that are not cooked, such as pasteurised egg products or commercially made products (mayonnaises, aioli, sauces, etc.).
2. Strict controls if raw eggs or egg products are used:
   - Safe delivery: use only clean, refrigerated, seamless eggs, with guaranteed traceability and within the preferred consumption period.
   - Hygiene in handling: frequent hand washing, use of gloves, strict separation between raw and cooked products, and disinfection of utensils and surfaces.
   - Time and temperature control: keep at ≤5 ºC for a maximum of 24 hours or apply the "2/4 hour rule" for products kept between 5-60 ºC.
3. Application of additional treatments:
   - Acidification: reduce the pH to ≤4.2 with ingredients such as lemon or vinegar, measuring and recording the value as a safety measure.
   - Effective heat treatment: apply processes such as pasteurisation to ensure *Salmonella* elimination.
4. Specific recommendations for desserts, smoothies or sauces with raw egg:
   - Use pasteurised egg in its different presentations (liquid, frozen, dried or with a treated shell).
   - Implement additional controls, such as reducing the a_w, to limit microbial proliferation.

6. Assessing the risk to public health derived from the consumption of meals prepared with raw eggs

Assessing the risk associated with the consumption of food preparations containing raw eggs in the field of catering requires integrating information on the prevalence of *S. enterica* in laying flocks, the mechanisms of egg contamination and exposure factors in the storage and handling phases. As noted above, eggs and egg products continue to be one of the main vehicles of transmission of *S.* Enteritidis and, to a lesser extent, *S.* Typhimurium, responsible for a high percentage of salmonellosis outbreaks associated with the consumption of food of avian origin in Europe (EFSA/ECDC, 2025).

The prevalence of *Salmonella* in laying hens in the European Union remains low, around 3-4 % for any serotype, with values of 0.3-0.5 % for the target serotypes (*S.* Enteritidis, *S.* Typhimurium and its monophasic variant) (EFSA, 2023) (MAPA, 2023). In Spain, the National *Salmonella* Control Program for Laying Hens reported a prevalence of 0.37 % in 2023, representing an approximate 40 % reduction compared to 2015. Despite this downward trend, *S.* Enteritidis continues to be the predominant serotype in human infections associated with egg consumption, with a clear correlation between its prevalence in flocks and its incidence in food outbreaks (Jones et al., 2022).

6.1 Internal contamination

As indicated in section 3.2 of this report, internal egg contamination is a low-frequency phenomenon, but of high epidemiological relevance. It is produced mainly by the colonisation of the ovary and oviduct by *S.* Enteritidis, which can integrate into albumen and reach the yolk before the shell forms. Field studies have detected internal contamination prevalences of less than 1 % in infected batches, and up to 3-4 % under challenging experimental conditions (FAO/WHO, 2002) (Kovac et al., 2021).

The EFSA quantitative risk model (2014) estimated an increased relative risk of disease of 1.4 for meals with raw (uncooked) egg and 1.5 for lightly cooked meals if the date of consumption was extended from 21 to 28 days. On the other hand, the FAO/WHO model (2002) placed the risk at between 0.2 and 4.5 cases per million contaminated rations, depending on the prevalence at origin and storage conditions. Taken together, these models confirm that the magnitude of the risk depends less on the initial dose and more on the time and temperature prior to consumption (Gurtler et al., 2023).

Keeping the eggs continuously cool until the time of breaking them can be an effective measure to limit the growth of the pathogen, as described above with the application of predictive microbiology models. At temperatures ≤7 ºC, the multiplication of *Salmonella* inside the egg is negligible, although the bacterium can survive for weeks (De Reu et al., 2020). Cooling prevents degradation of the vitelline membrane, minimises *Salmonella* migrating into the yolk, and reduces the risk of cross-shell penetration by condensation. Under this scenario, refrigeration until the egg is cracked and immediate consumption, the risk of foodborne infection by *S.* Enteritidis can be considered low, although a residual risk persists, especially in situations of pooling of large volumes of fresh unpasteurised eggs, where a single contaminated egg could cause an outbreak.

6.2 External contamination

Contamination of the shell surface is much more frequent than internal contamination. Various European studies place its prevalence between 5 and 24 %, depending on the conditions of production and handling (De Reu et al., 2020) (Jones et al., 2022). This contamination occurs mainly through faecal deposition during laying, contact with contaminated surfaces or environmental accumulation of dust and organic matter on the farm.

In catering settings, the risk arising from external contamination depends on whether there is transfer when the eggs are cracked, especially when the shell is broken without adequate hygiene measures. Refrigeration reduces the risk of bacterial penetration, but does not prevent possible cross-contamination between the shell, the handler's hands, and utensils. Recent studies have shown that the transfer of *S.* Enteritidis from the surface of the egg to its contents can occur in less than 1 % of cases with careful handling, but exceed 10 % when there are cracks or direct contact (FAO/WHO, 2002).

Under refrigerated conditions up to cracking and immediate consumption, the risk associated with exclusively external contamination can be considered low, provided that good hygiene practices are applied in handling: hand washing, separation of utensils, elimination of dirty or cracked eggs, and cracking immediately before use. However, in the absence of these practices, the risk can be significant, as subsequent heat treatment is not applied.

6.3 Comparative risk assessment

The risk associated with internal contamination by *S.* Enteritidis is less frequent but of greater potential severity, since a single contaminated unit can generate outbreaks through pooling. On the other hand, external contamination, although more common, is closely linked to compliance with hygienic standards at the point when the egg is cracked.

EFSA's attribution studies (2023) estimate that approximately 41 % of salmonellosis outbreaks in the European Union are still linked to the consumption of eggs or products thereof, despite improved on-farm control programmes. This evidences the need to maintain an integrated chain of control from production to catering environments (EFSA/ECDC, 2025).

Refrigeration until cracking and immediate consumption reduces the risk to low levels, but does not eliminate it completely. The use of pasteurised egg products in raw or undercooked preparations continues to be the only measure that guarantees risk reduction (FAO/WHO, 2002).

The comparative analysis of the regulations and practices of the Member States of the European Union on the use of raw eggs in catering and food preparation reveals a variety of approaches, although all are aligned with the general principles of food safety established in Regulation (EC) No. 852/2004, on the hygiene of foodstuffs (EU, 2004). In most countries, the use of raw eggs is not expressly prohibited, but it is conditional on compliance with hygiene, origin control and refrigeration requirements, or its replacement with pasteurised egg products is recommended, especially in preparations without heat treatment.

Some Member States, such as Germany, Denmark, Ireland and Slovakia, apply specific heat treatment criteria. In Germany, for example, dishes intended for vulnerable groups must undergo a

treatment that guarantees the elimination of *Salmonella* or an equivalent process. In other cases, the use of raw egg is permitted, provided that temperature and time restrictions apply (such as serving hot food within 2 hours of preparation, or refrigeration to ≤7 ºC in the case of cold foods), in addition to requiring clear labelling with the advice "consume immediately" for consumption outside the establishment.

In Denmark, legislation allows for the substitution of heat treatment by documented processes with equivalent effectiveness, and exempts establishments that fully cook food at ≥75 ºC or that use individually served eggs from approved packing centres from this obligation. Serving eggs passed through water or fried is also allowed, provided that there is process control and traceability.

Other countries, such as France, Portugal, Austria, Romania or Estonia, do not impose specific restrictions, limiting themselves to applying the general rules of hygiene and self-control. However, other countries such as Italy or Belgium expressly recommend the use of eggs or pasteurised egg products to prevent outbreaks of salmonellosis.

Some countries have more detailed provisions. For example, in Slovakia it is required that dishes with eggs not fully cooked are made only with eggs from farms officially controlled against *Salmonella*, while the use of egg products for confectionery establishes a minimum heat treatment of ≥72 ºC for 15 minutes, and the use of raw eggs in delicatessens or cold sauces such as mayonnaise, for which only pasteurised egg products are allowed, is prohibited.

Therefore, under the proposed catering scenario (eggs refrigerated until breaking and immediate consumption), the risk of foodborne infection through *S.* Enteritidis in eggs with internal contamination is low, while the risk associated with *S.* Typhimurium is residual. In the case of exclusively external contamination, the risk is minimised (although not eliminated) when proper hygienic practices are applied in handling, but can be significant if deficiencies in the shell occur.

Zero risk is not achievable through refrigeration or through any individual measure, since there is always a residual probability of contamination or handling failure. However, the use of pasteurised egg products in raw processes remains the most effective measure to reduce the risk of exposure to the consumer. Consequently, the implementation of a "multi-barrier" strategy that combines continuous refrigeration, strict hygienic practices, control of origin and suppliers, and preference for pasteurised egg products, represents the most effective and realistic approach to minimise, although never completely eliminate, the risk of salmonellosis in the catering sector (EFSA/ECDC, 2025).

Conclusions of the Scientific Committee

Applying an approach based on the application of predictive models has made it possible to accurately quantify the probability and growth rate of the pathogen based on the storage conditions of time and temperature, pH and water activity (a_w).

The analysis carried out confirms that storage temperature is the decisive factor in determining the microbiological shelf life of meals prepared from eggs and egg products. In case of keeping eggs at temperatures equal to or lower than 4 ºC, the risk of proliferation of *Salmonella* spp. is negligible even in unpasteurised products. However, it should be borne in mind that the storage time of meals

prepared at this temperature should be as short as possible in order to avoid the proliferation of other foodborne pathogens that can grow at low temperatures, such as *Listeria monocytogenes*. Based on the estimates provided by the model, growth of *Salmonella* spp. at 8 ºC for 24 hours is very limited, being less than 0.2 log CFU/g in all matrices tested. However, it is necessary to take into account the impact of possible abuses in the storage conditions that can favour the growth of the pathogen, especially in matrices such as omelette, tiramisu or tartare. Therefore, it is important to properly control the storage temperature of prepared foods throughout their shelf life.

On the other hand, we conclude that the intrinsic properties of each matrix notoriously influence the growth of *Salmonella* spp. The liquid yolk and the whole egg present combinations of pH and a_w very favourable to the development of *Salmonella*, which require continuous and rigorous thermal control. In contrast, the liquid white, thanks to its alkaline pH and the presence of proteins with antimicrobial activity such as ovotransferrin and lysozyme, shows a practically null growth probability even under conditions of thermal abuse. In prepared foods such as omelette or tiramisu, the combination of ingredients and moisture available increases the risk, while in cured eggs, the low values of a_w act as a natural barrier against the proliferation of *Salmonella* spp., limiting the risk even in less favourable scenarios.

Therefore, we conclude that the refrigeration storage conditions stipulated in Royal Decree 1086/2020 (BOE, 2020) for prepared meals (4 ºC if its shelf life is greater than 24 hours and 8 ºC if its shelf life is less than 24 hours) are sufficiently safe with respect to the risk of proliferation of *Salmonella* spp. in foods made with raw eggs and subjected to heat treatment, as well as in those not subjected to heat treatment made with pasteurised egg products. This safety is maintained as long as the starting microbiological quality is guaranteed, as well as good hygiene and handling practices during the preparation and storage of prepared meals.

Moreover, although the prevalence of *S.* Enteritidis and *S.* Typhimurium in businesses that have laying hens is currently low, the risk associated with the consumption of raw egg preparations can be considered low but not negligible. Refrigeration until the time of breaking the egg is an effective measure to limit bacterial proliferation, but does not eliminate the possibility of contamination or outbreaks if there are failures in handling or large volumes of fresh eggs are mixed. Therefore, the risk can be considered low but not negligible, and must be managed through a comprehensive control system that guarantees its permanence within the acceptable margins of food safety. In the context of catering, the combination of a reduced but persistent prevalence, together with the high capacity to spread the pathogen and the severity of the associated cases, makes it necessary to maintain a preventive management approach based on the strict application of good hygiene practices, continuous refrigeration and the preferential use of pasteurised egg products.

The results show that a management strategy based on rigorous temperature control, detailed knowledge of the intrinsic properties of each matrix and the appropriate use of predictive models can ensure the food safety of meals prepared from eggs and egg products.

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Annex I

Salmonella growth data used in the predictive microbiology model for the validation of egg and egg product storage conditions

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
1	Egg white	No	16	6.2	-	*S.* Enteritidis, Strain(s): C398 19299-521	0.0875	-	-	-
2	Egg white	No	37	6.2	-	*S.* Enteritidis, Strain(s): C398 19299-521	-	-	-	-
3	Egg white	No	37	6.2	-	*S.* Enteritidis, Strain(s): C398 19299-521	0.627	-	-	-
4	Pastry cream	Yes	7.9	6.6	0.98	*S.* Enteritidis, Strain(s): P125592SN+ P125678SN+ P167627NS+P167807SN+	0.00194	76.8	9.3	-
5	Pastry cream	Yes	7.9	6.6	0.98	*S.* Enteritidis, Strain(s): P125592SN+ P125678SN+ P167627NS+P167807SN+	0.0055	76.8	9.3	-
6	Pastry cream	Yes	12	6.6	0.98	*S.* Enteritidis, Strain(s): P125592SN+ P125678SN+ P167627NS+P167807SN+	0.0177	76.8	9.3	-
7	Pastry cream	Yes	12	6.6	0.98	*S.* Enteritidis, Strain(s): P125592SN+ P125678SN+ P167627NS+P167807SN+	0.00511	76.8	9.3	-
8	Pastry cream	Yes	19	6.6	0.98	*S.* Enteritidis, Strain(s): P125592SN+ P125678SN+ P167627NS+P167807SN+	0.124	76.8	9.3	-
9	Pastry cream	Yes	19	6.6	0.98	*S.* Enteritidis, Strain(s): P125592SN+ P125678SN+ P167627NS+P167807SN+	0.11	76.8	9.3	-
10	Pastry cream	Yes	25	6.6	0.98	*S.* Enteritidis, Strain(s): P125592SN+ P125678SN+ P167627NS+P167807SN+	-	76.8	9.3	-
11	Pastry cream	Yes	25	6.6	0.98	*S.* Enteritidis, Strain(s): P125592SN+ P125678SN+ P167627NS+P167807SN+	-	76.8	9.3	-
12	Pastry cream	Yes	8	6.7	0.998	*S.* Enteritidis, Strain(s): P125592 P125678	0.0195	-	-	0.3
13	Pastry cream	Yes	8	6.7	-	*S.* Enteritidis, Strain(s): P125592 P125678	0.00838	-	-	-
14	Pastry cream	Yes	8	6.7	-	*S.* Enteritidis, Strain(s): P125592 P125678	0.011	-	-	-
15	Pastry cream	Yes	8	6.7	0.998	*S.* Enteritidis, Strain(s): P125592 P125678	0.0207	-	-	0.3
18	Quiche	Yes	8	6	0.994	*S.* Enteritidis, Strain(s): P125592 P125678	0.00835	-	-	1.1
19	Quiche	Yes	8	6	0.994	*S.* Enteritidis, Strain(s): P125592 P125678	0.00617	-	-	1.1
20	Pastry cream	Yes	12	6.7	-	*S.* Enteritidis, Strain(s): P125592 P125678	0.0452	-	-	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
21	Pastry cream	Yes	12	6.7	-	*S.* Enteritidis, Strain(s): P125592 P125678	0.0461	-	-	-
22	Pastry cream	Yes	12	6.7	0.998	*S.* Enteritidis, Strain(s): P125592 P125678	0.0349	-	-	0.3
23	Pastry cream	Yes	12	6.7	0.998	*S.* Enteritidis, Strain(s): P125592 P125678	0.035	-	-	0.3
26	Quiche	Yes	12	6	0.994	*S.* Enteritidis, Strain(s): P125592 P125678	0.0244	-	-	1.1
27	Quiche	Yes	12	6	0.994	*S.* Enteritidis, Strain(s): P125592 P125678	0.0237	-	-	1.1
28	Pastry cream	Yes	25	6.9	-	*S.* Enteritidis, Strain(s): P125592 P125678	0.271	-	-	-
29	Pastry cream	Yes	18	6.7	-	*S.* Enteritidis, Strain(s): P125592 P125678	0.0947	-	-	-
30	Pastry cream	Yes	18	6.7	-	*S.* Enteritidis, Strain(s): P125592 P125678	0.0974	-	-	-
31	Pastry cream	Yes	18	6.7	0.998	*S.* Enteritidis, Strain(s): P125592 P125678	0.0921	-	-	0.3
32	Pastry cream	Yes	18	6.7	0.998	*S.* Enteritidis, Strain(s): P125592 P125678	0.0897	-	-	0.3
33	Quiche	Yes	18	6	-	*S.* Enteritidis, Strain(s): P125592 P125678	0.0864	-	-	-
34	Quiche	Yes	18	6	-	*S.* Enteritidis, Strain(s): P125592 P125678	0.117	-	-	-
35	Quiche	Yes	18	6	0.994	*S.* Enteritidis, Strain(s): P125592 P125678	0.0942	-	-	1.1
36	Quiche	Yes	18	6	0.994	*S.* Enteritidis, Strain(s): P125592 P125678	0.0699	-	-	1.1
37	Pastry cream	Yes	25	6.9	-	-	-	-	-	-
38	Pastry cream	Yes	25	6.9	0.998	*S.* Enteritidis, Strain(s): P125592 P125678	0.234	-	-	0.3
39	Pastry cream	Yes	25	6.9	0.998	*S.* Enteritidis, Strain(s): P125592 P125678	0.231	-	-	0.3
40	Quiche	Yes	25	6	-	*S.* Enteritidis, Strain(s): P125592 P125678	0.261	-	-	-
41	Quiche	Yes	25	6	-	*S.* Enteritidis, Strain(s): P125592 P125678	0.277	-	-	-
42	Quiche	Yes	25	6	0.994	*S.* Enteritidis, Strain(s): P125592 P125678	0.143	-	-	1.1
43	Quiche	Yes	25	6	0.994	*S.* Enteritidis, Strain(s): P125592 P125678	0.156	-	-	1.1
44	Egg white	No	17.5	-	-	*S.* Enteritidis, Serotype(s): PT8	0.102	-	-	-
45	Egg white	No	10	-	-	*S.* Enteritidis, Serotype(s): PT8	0.0229	-	-	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
49	Egg white	No	10	-	-	*S.* Enteritidis, Serotype(s): PT8	0.0271	-	-	-
54	Whole egg (yolk surface)	No	17.5	-	-	*S.* Enteritidis, Serotype(s): PT8	0.0167	-	-	-
56	Egg white	No	17.5	-	-	*S.* Enteritidis, Serotype(s): PT8	0.0833	-	-	-
58	Whole egg (yolk surface)	No	17.5	-	-	*S.* Enteritidis, Serotype(s): PT8	0.0333	-	-	-
59	Albumen	No	17.5	-	-	*S.* Enteritidis, Serotype(s): PT8	-	-	-	-
60	Egg white	No	17.5	-	-	*S.* Enteritidis, Serotype(s): PT8	0.0521	-	-	-
62	Whole egg (yolk surface)	No	25	-	-	*S.* Enteritidis, Serotype(s): PT8	0.0354	-	-	-
64	Egg white	No	25	-	-	*S.* Enteritidis, Serotype(s): PT8	0.0375	-	-	-
66	Whole egg (yolk surface)	No	25	-	-	*S.* Enteritidis, Serotype(s): PT8	0.0479	-	-	-
67	Albumen	No	25	-	-	*S.* Enteritidis, Serotype(s): PT8	-	-	-	-
111	Liquid whole egg	Yes	10	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0553	-	-	-
112	Liquid whole egg	Yes	10	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0254	-	-	-
114	Sugared yolk	Yes	10	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.019	-	10	-
115	Sugared yolk	Yes	10	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0256	-	10	-
116	Liquid whole egg	Yes	10	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0262	-	-	-
120	Albumen	Yes	20	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	-	-	-	-
121	Albumen	Yes	20	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	-	-	-	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
122	Albumen	Yes	20	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0184	-	-	-
123	Albumen	Yes	20	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0173	-	-	-
124	Sugared yolk	Yes	20	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0625	-	10	-
125	Sugared yolk	Yes	20	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0658	-	10	-
126	Sugared yolk	Yes	20	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0479	-	10	-
127	Sugared yolk	Yes	20	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0484	-	10	-
128	Liquid whole egg	Yes	20	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0848	-	-	-
133	Liquid whole egg	Yes	20	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0918	-	-	-
134	Liquid whole egg	Yes	20	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0882	-	-	-
135	Liquid whole egg	Yes	20	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.071	-	-	-
136	Liquid whole egg	Yes	30	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.098	-	-	-
137	Liquid whole egg	Yes	30	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.088	-	-	-
138	Liquid whole egg	Yes	30	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0622	-	-	-
139	Liquid whole egg	Yes	30	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.181	-	-	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
140	Albumen	Yes	30	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0144	-	-	-
141	Albumen	Yes	30	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.102	-	-	-
142	Albumen	Yes	30	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0246	-	-	-
143	Albumen	Yes	30	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0214	-	-	-
144	Sugared yolk	Yes	30	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0682	-	10	-
145	Sugared yolk	Yes	30	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.111	-	10	-
153	Albumen	Yes	30	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.112	-	-	-
154	Sugared yolk	Yes	30	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.143	-	10	-
155	Liquid whole egg	Yes	37	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.169	-	-	-
156	Liquid whole egg	Yes	37	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.25	-	-	-
157	Liquid whole egg	Yes	37	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.239	-	-	-
158	Liquid whole egg	Yes	37	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.467	-	-	-
159	Albumen	Yes	37	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0595	-	-	-
160	Albumen	Yes	37	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.0471	-	-	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
161	Albumen	Yes	37	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	-	-	-	-
162	Albumen	Yes	37	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.2	-	-	-
163	Sugared yolk	Yes	37	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.387	-	10	-
164	Sugared yolk	Yes	37	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.234	-	10	-
165	Sugared yolk	Yes	37	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.539	-	10	-
166	Sugared yolk	Yes	37	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.473	-	10	-
169	Sugared yolk	Yes	37	6.5	0.88	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.539	-	10	-
170	Sugared yolk	Yes	37	6.5	0.88	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.473	-	10	-
177	Egg white	No	37	7.9	-	*S.* Enteritidis, Strain(s): E40	0.47	-	-	-
178	Egg white	No	37	9	-	*S.* Enteritidis, Strain(s): E40	-	-	-	-
179	Egg white	No	37	6.6	-	*S.* Enteritidis, Strain(s): E40	0.478	-	-	-
180	Egg white	No	37	8.7	-	*S.* Enteritidis, Strain(s): E40	-	-	-	-
181	Egg white	No	10	6.4	-	*S.* Enteritidis, Strain(s): E40	0.0313	-	-	-
182	Egg white	No	10	6.4	-	*S.* Enteritidis, Strain(s): E40	0.0287	-	-	-
183	Albumen	No	10	7.6	-	*S.* Typhimurium, Strain(s): FRI-S9	0.0234	-	-	-
184	Egg white	No	25	6.4	-	*S.* Enteritidis, Strain(s): E40	0.166	-	-	-
185	Egg white	No	25	6.4	-	*S.* Enteritidis, Strain(s): E40	0.188	-	-	-
186	Albumen	No	25	7.6	-	*S.* Enteritidis, Strain(s): E40	0.152	-	-	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
187	Albumen	No	25	7.6	-	*S.* Enteritidis, Strain(s): E40	0.23	-	-	-
188	Egg white	No	25	6.4	-	*S.* Typhimurium, Strain(s): FRI-S9	0.158	-	-	-
189	Egg white	No	25	6.4	-	*S.* Typhimurium	0.188	-	-	-
190	Albumen	No	25	7.6	-	*S.* Typhimurium, Strain(s): FRI-S9	0.136	-	-	-
191	Albumen	No	25	7.6	-	*S.* Typhimurium, Strain(s): FRI-S9	0.186	-	-	-
192	Egg white	No	25	6.4	-	*S.* Heidelberg, Strain(s): FRI-S13	0.146	-	-	-
193	Egg white	No	25	6.4	-	*S.* Heidelberg, Strain(s): FRI-S13	0.23	-	-	-
194	Albumen	No	25	7.6	-	*S.* Heidelberg, Strain(s): FRI-S13	0.146	-	-	-
195	Albumen	No	25	7.6	-	*S.* Heidelberg, Strain(s): FRI-S13	0.166	-	-	-
196	Liquid whole egg	No	10	-	-	*S.* Enteritidis, *S.* Enteritidis, *S.* Typhimurium, *S.* blockley, *S.* Heidelberg	0.0184	-	-	-
197	Liquid whole egg	No	15	-	-	*S.* Enteritidis, *S.* Enteritidis, *S.* Typhimurium, *S.* blockley, *S.* Heidelberg	0.0688	-	-	-
198	Liquid whole egg	No	20	-	-	*S.* Enteritidis, *S.* Enteritidis, *S.* Typhimurium, *S.* blockley, *S.* Heidelberg	0.112	-	-	-
199	Liquid whole egg	No	25	-	-	*S.* Enteritidis, *S.* Enteritidis, *S.* Typhimurium, *S.* blockley, *S.* Heidelberg	0.198	-	-	-
200	Liquid whole egg	No	30	-	-	*S.* Enteritidis, *S.* Enteritidis, *S.* Typhimurium, *S.* blockley, *S.* Heidelberg	0.28	-	-	-
201	Liquid whole egg	No	35	-	-	*S.* Enteritidis, *S.* Enteritidis, *S.* Typhimurium, *S.* blockley, *S.* Heidelberg	0.388	-	-	-
202	Liquid whole egg	No	37	-	-	*S.* Enteritidis, *S.* Enteritidis, *S.* Typhimurium, *S.* blockley, *S.* Heidelberg	0.597	-	-	-
203	Liquid whole egg	No	39	-	-	*S.* Enteritidis, *S.* Enteritidis, *S.* Typhimurium, *S.* blockley, *S.* Heidelberg	0.521	-	-	-
216	Albumen	Yes	10	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.00258	-	-	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
217	Albumen	Yes	10	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.00533	-	-	-
218	Albumen	Yes	10	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.00237	-	-	-
219	Liquid whole egg	Yes	10	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0263	-	-	-
220	Liquid whole egg	Yes	10	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0277	-	-	-
221	Sugared yolk	Yes	10	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0281	-	10	-
222	Sugared yolk	Yes	10	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.029	-	10	-
223	Sugared yolk	Yes	10	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0262	-	10	-
224	Liquid whole egg	Yes	10	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0276	-	-	-
228	Albumen	Yes	15	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0131	-	-	-
229	Albumen	Yes	15	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0105	-	-	-
230	Albumen	Yes	15	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0113	-	-	-
231	Sugared yolk	Yes	15	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0682	-	10	-
232	Sugared yolk	Yes	15	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.072	-	10	-
233	Sugared yolk	Yes	15	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0642	-	10	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
234	Liquid whole egg	Yes	15	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.106	-	-	-
236	Liquid whole egg	Yes	15	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.103	-	-	-
239	Liquid whole egg	Yes	15	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.099	-	-	-
240	Liquid whole egg	Yes	20	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.195	-	-	-
241	Liquid whole egg	Yes	20	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.175	-	-	-
242	Liquid whole egg	Yes	20	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.19	-	-	-
243	Albumen	Yes	20	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0274	-	-	-
244	Albumen	Yes	20	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0253	-	-	-
245	Albumen	Yes	20	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0318	-	-	-
246	Sugared yolk	Yes	20	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.165	-	10	-
247	Sugared yolk	Yes	20	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.161	-	10	-
248	Sugared yolk	Yes	20	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.164	-	10	-
252	Liquid whole egg	Yes	25	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.453	-	-	-
253	Liquid whole egg	Yes	25	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.45	-	-	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
254	Liquid whole egg	Yes	25	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.446	-	-	-
255	Albumen	Yes	25	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0295	-	-	-
256	Albumen	Yes	25	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0521	-	-	-
257	Albumen	Yes	25	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0474	-	-	-
258	Sugared yolk	Yes	25	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.346	-	10	-
259	Sugared yolk	Yes	25	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.336	-	10	-
260	Sugared yolk	Yes	25	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.33	-	10	-
264	Liquid whole egg	Yes	30	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.605	-	-	-
265	Liquid whole egg	Yes	30	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.574	-	-	-
266	Liquid whole egg	Yes	30	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.579	-	-	-
267	Albumen	Yes	30	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0467	-	-	-
268	Albumen	Yes	30	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0431	-	-	-
269	Albumen	Yes	30	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0257	-	-	-
270	Sugared yolk	Yes	30	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.44	-	10	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
271	Sugared yolk	Yes	30	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.43	-	10	-
272	Sugared yolk	Yes	30	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.428	-	10	-
276	Liquid whole egg	Yes	37	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.863	-	-	-
277	Liquid whole egg	Yes	37	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.844	-	-	-
278	Liquid whole egg	Yes	37	7.8	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.844	-	-	-
279	Albumen	Yes	37	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0332	-	-	-
280	Albumen	Yes	37	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.0327	-	-	-
281	Albumen	Yes	37	8.9	-	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.022	-	-	-
282	Sugared yolk	Yes	37	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.502	-	10	-
283	Sugared yolk	Yes	37	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.508	-	10	-
284	Sugared yolk	Yes	37	6.5	0.98	*S.* Typhimurium, Strain(s): 10-TX (poultry) 7470C-1 (pigs)	0.519	-	10	-
300	Steamed egg	Yes	18	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.189	-	-	1
301	Scrambled egg	Yes	18	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.212	-	-	1
302	Steamed egg	Yes	18	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.195	-	-	-
303	Steamed egg	Yes	18	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.222	-	-	-
304	Steamed egg	Yes	18	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.192	-	-	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
305	Scrambled egg	Yes	18	-	0.995	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.0692	-	-	1
306	Scrambled egg	Yes	18	-	0.995	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.156	-	-	1
307	Scrambled egg	Yes	18	-	0.995	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.085	-	-	1
308	Steamed egg	Yes	22	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.317	-	-	-
309	Scrambled egg	Yes	22	-	0.995	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.206	-	-	1
310	Steamed egg	Yes	22	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.273	-	-	-
311	Steamed egg	Yes	22	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.287	-	-	-
312	Steamed egg	Yes	22	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.266	-	-	-
313	Scrambled egg	Yes	22	-	0.995	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.0767	-	-	1
314	Scrambled egg	Yes	22	-	0.995	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.157	-	-	1
315	Scrambled egg	Yes	22	-	0.995	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.148	-	-	1
316	Steamed egg	Yes	37	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	-	-	-	-
317	Scrambled egg	Yes	37	-	0.995	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.607	-	-	1
318	Steamed egg	Yes	37	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.708	-	-	-
319	Steamed egg	Yes	37	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.515	-	-	-
320	Steamed egg	Yes	37	-	-	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.373	-	-	-
321	Scrambled egg	Yes	37	-	0.995	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.551	-	-	1
322	Scrambled egg	Yes	37	-	0.995	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.471	-	-	1
323	Scrambled egg	Yes	37	-	0.995	*S.* anatum, *S.* Enteritidis, *S.* Stanley	0.39	-	-	1
367	Liquid whole egg	Yes	20	7	-	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.102	-	-	-
369	Liquid whole egg	Yes	20	7	-	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.114	-	-	-
370	Liquid whole egg	Yes	20	7	-	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.0535	-	-	-
371	Liquid whole egg	Yes	20	7	-	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.0993	-	-	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
372	Liquid whole egg	Yes	20	7	0.992	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.103	-	-	1.5
373	Liquid whole egg	Yes	20	7	0.992	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.102	-	-	1.5
374	Liquid whole egg	Yes	20	7	0.992	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.211	-	-	1.5
375	Liquid whole egg	Yes	20	7	0.992	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.0922	-	-	1.5
376	Liquid whole egg	Yes	20	7	0.992	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.118	-	-	1.5
377	Liquid whole egg	Yes	20	7	0.983	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.0726	-	-	3
378	Liquid whole egg	Yes	20	7	0.983	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.025	-	-	3
379	Liquid whole egg	Yes	20	7	0.983	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.0311	-	-	3
380	Liquid whole egg	Yes	20	7	0.983	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.0163	-	-	3
381	Liquid whole egg	Yes	20	7	0.983	*S.* Enteritidis, Strain(s): ADRIANIE-1119590	0.0193	-	-	3
382	Eggshell	No	10	9	-	*S.* pullorum	0.0271	-	-	-
383	Eggshell	No	20	9	-	*S.* pullorum	-	-	-	-
384	Eggshell	No	20	7	-	*S.* pullorum	0.0583	-	-	-
385	Egg white	No	45	-	-	*S.* Enteritidis, Strain(s): MG03835 MG04498 MG07928 MB00617 MB00629	0.424	-	-	-
386	Egg white	No	45	-	-	*S.* Enteritidis, Strain(s): MG03835 MG04498 MG07928 MB00617 MB00629	0.587	-	-	-

ID	Matrix	Pasteurised	Temperature (ºC)	pH	Water activity (a_w)	Serotypes	Maximum growth rate (log CFU/h)	Humidity (%)	Sugars (%)	NaCl (%)
389	Liquid whole egg	Yes	42	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.54	-	-	-
390	Liquid whole egg	Yes	42	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.507	-	-	-
391	Albumen	Yes	42	8.9	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.304	-	-	-
393	Sugared yolk	Yes	42	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.911	-	10	-
394	Sugared yolk	Yes	42	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.84	-	10	-
397	Liquid whole egg	Yes	42	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.439	-	-	-
400	Liquid whole egg	No	41	-	-	*S.* Enteritidis, *S.* Typhimurium, *S.* blockley, *S.* Heidelberg	0.523	-	-	-
401	Liquid whole egg	No	43	-	-	*S.* Enteritidis, *S.* Enteritidis, *S.* Typhimurium, *S.* blockley, *S.* Heidelberg	0.287	-	-	-
402	Liquid whole egg	Yes	42	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.987	-	-	-
403	Liquid whole egg	Yes	42	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	1.0207	-	-	-
404	Liquid whole egg	Yes	42	7.8	-	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.96	-	-	-
408	Sugared yolk	Yes	42	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.797	-	10	-
409	Sugared yolk	Yes	42	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.772	-	10	-
410	Sugared yolk	Yes	42	6.5	0.98	*S.* Typhimurium, Strain(s): 10 TX (poultry) 7470C-1 (pigs)	0.737	-	10	-