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Comparison of european surveillance and control programs for *Salmonella* in broiler and Turkey chains

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ABSTRACT

For the past years, *Salmonella* has been one of the major foodborne pathogens in Europe, leading to the development of several control efforts to reduce its impact on human health. Poultry meat has been consistently implicated in foodborne cases of salmonellosis. One of the strategies to lessen the burden of salmonellosis in humans was the implementation of national control programs (NCPs) for *Salmonella* in broilers and turkeys aiming for reductions in these animal populations. In this paper, a description and comparison of the *Salmonella* surveillance and control programs that are currently implemented for the broiler and turkey chains in different European countries was performed.

All the countries studied have set multiple surveillance and control actions for *Salmonella* at different stages of the broiler and turkey chains, namely the feed, farm and meat levels. Although most of the control programs are aligned with European Union (EU) regulations, some differences were observed, mostly regarding feed controls, farm surveillance schemes, target serovars and the handling of positive flocks. Overall, these differences had a regional pattern, with the Nordic countries having more detailed control programs with a zero-tolerance in meat. The remaining countries generally follow EU legislation, but in some cases, additional specifications were identified by this study.

Despite the positive impact of these control programs on the reduction of human cases of salmonellosis, the decreasing tendency has reached a stall. The authors suggest that the NCPs are regularly revised within the framework of risk-based meat assurance systems, and the inclusion of additional target serovars which are simultaneously prevalent in broiler and turkey flocks and relevant in terms of public health within a country or a

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region. Furthermore, within the revision of NCPs, sampling schemes and strategies need to be consistent, following the risk management approach that has led to very low prevalences of *Salmonella* in poultry meat in some European countries.

1. Introduction

Salmonella is among the most notorious foodborne hazards and has been estimated to be the second most frequently implicated bacterial pathogen in human diarrheal diseases worldwide (Kirk et al., 2015). Also, in Europe, *Salmonella* is a major cause of foodborne outbreaks, and during recent years, salmonellosis has had a relatively stable yearly trend regarding numbers of reported human cases (EFSA & ECDC, 2022). In relation to the broiler and turkey meat production chain, this zoonotic bacterium can commonly be found in the gastrointestinal tract of poultry and on their feathers, while contaminated poultry meat is specified as one of the major food vehicles for human salmonellosis (Facciolà et al., 2017; Nair & Kollanoor Johny, 2019). *Salmonella* was assessed by the European Food Safety Authority (EFSA) as a high priority hazard in poultry due to the high incidence of human salmonellosis and the important attribution of poultry (EFSA, 2012). Moreover, the prevalence of *Salmonella* in poultry meat is still high in many European countries. The serovar Enteritidis, adapted to birds, has caused a slow pandemic since the 1970s, being the serovar most frequently reported causing salmonellosis in humans (Velge et al., 2005). Furthermore, *Salmonella* currently causes the highest number of foodborne outbreaks in the European Union (EU) annually, and the main sources of *Salmonella* outbreaks are constantly eggs and egg products (EFSA & ECDC, 2022).

Salmonella control within the EU is devised using the farm to fork principle. According to Regulation (EC) No 2160/2003 and the Zoonosis Directive 2003/99/EC (EC, 2003a,b), *Salmonella* occurrence must be monitored in feed, animals and food, and the data collected should be reported on a mandatory basis to EFSA to be included in the annual zoonoses reports. Different levels of harmonisation occur for *Salmonella* data collected along the food chain by the EU member states (EU-MSs) in the context of zoonosis data collection. The highest level of comparability and harmonisation is for the data regulated by current legislation (e.g. *Salmonella* national control programs (NCPs) in poultry populations), and a lower level for data collected according to national requirements.

In some EU-MSs, *Salmonella* control programs were implemented first on a voluntary basis and later defined by legislation and extended to all EU-MSs, at least at primary production level. In Sweden, for example, the first *Salmonella* control measures go back to the 1950s in the feed sector. Later, controls at farm and abattoir level were set, and further were specified by EU legislation from 2009 onwards. The aim of all control activities at the different production stages of the broiler and turkey production chains is to prevent the entry of *Salmonella*. However, at the primary production level, the focus is on the serovars which present a major risk to public health, and so are defined as "target serovars" by EFSA (EC, 2003b; EFSA, 2019). In different EU-MSs, countries of the European Economic Area (EEA) and in non-EU countries in Europe, different control strategies have been implemented. Regardless of the strategy adopted, the use of antimicrobials with the specific intention of controlling *Salmonella* in poultry is not allowed within the EU (EC, 2006), due the possible public health implications of such a measure, namely the development of antimicrobial resistance of other gut bacteria and the selection and dissemination of antimicrobial-resistant *Salmonella* isolates.

According to current EU legislation, *Salmonella* surveillance has been based on different pillars. The surveillance focuses on the targets of prevalence reduction, which have been defined following a risk-based approach, and such targets are progressively updated and modulated according to the evolution of the EU epidemiological situation. Moreover, the surveillance covers the entire poultry production chain, and different activities are implemented by the food business operators (FBOs) and the competent authorities (CAs) (EC, 2017). For *Salmonella*, the surveillance approaches starting at primary production level along the food chain are synergistic and stand as a very unique combination between FBO's and CA's controls and surveillance actions, since there are no similar examples for the other zoonotic agents listed in the Zoonosis Directive (2003/99/EC) (EC, 2003a). Additionally, NCPs are set, based on the epidemiological situation in different countries. All findings of *Salmonella* in intra-community traded or imported materials for food and feeds are reported in the Rapid Alert System for Food and Feed (RASFF), with a legal basis in Regulation (EC) No 178/2002, Article 50 (EC, 2002).

The aim of this paper was to describe and compare the different surveillance and control programs that are implemented for *Salmonella* for broilers and turkeys in different European countries, and to assess their public health impact.

2. Materials and methods

This work was carried out within the European network of the COST Action 18,105 – RIBMINS (risk-based meat inspection and integrated meat safety assurance; https://ribmins.com). An international working group of professionals from the animal health, food safety and public health areas as well as academia was formed, with representatives from Denmark, Estonia, Finland, France, Germany, Italy, Norway, Poland, Portugal, Serbia and Sweden. Information and data were collected from different sources, namely scientific papers, publicly available national and international legislation, official reports and the so-called grey literature. The collected information concerned the control programs for *Gallus gallus* breeding and broiler flocks, breeding and fattening turkey flocks, and the human *Salmonella* monitoring programs.

3. Results

3.1. Mandatory surveillance and control actions

In all the participating countries except Serbia, the surveillance of *Salmonella* in feed and related control actions are carried out according to EU regulations. At feed level, control actions are laid down in a general way, not specifically focusing on *Salmonella* in several EU regulations (EC, 2002; 2004a; 2005a; 2009a,b; 2011a). These regulations comprise official control actions and surveillance, including sampling and control by FBOs, which must be implemented in the company specific hazard analysis and critical control point (HACCP) system. The purposes are to produce safe feed, and to ensure that no microbiological or chemical hazards enter the food chain via livestock. Hence, if feed samples test positive for *Salmonella*, they cannot be used as animal feed without additional heat treatment effective in destroying the pathogen. Additionally, cleaning and disinfection of the equipment and feed holding places need to be carried out. These control measures are implemented at national level, as all the countries are enabled to set national legislative controls and action plans.

Serbia is not an EU-MS or EEA country; however, as an EU-candidate, the national Serbian Regulation is generally in line with relevant EU regulations. Namely, all relevant feed hygiene requirements of the Regulation (EC) No 183/2005 (EC, 2005a) are laid down in the National Regulation on General and Specific Feed Hygiene Conditions (Republic of Serbia, 2010a). Furthermore, by the Regulation on Feed Safety Monitoring Program (Republic of Serbia, 2021), feed level control is

Table 1
Controls for *Salmonella* in feed.

Country	Sample types	Sample frequency	Control actions
Denmark	Batches of feed materials not intended for heating directly delivered to farms (soybean meal, sunflower meal and rapeseed cake). Environmental samples collected during feed processing at feed processing plants. Samples from transport vehicles prior to loading feed compounds.	Feed samples are tested anywhere between one to four times a year. The focus of feed sampling is on batches >10 tons. If the quantity of feed >500 tons, multiple samples are obtained. Time of production and production lines are also a part of the risk-based criteria for sampling.	In the case of minimal infringements, guidance is provided on preventing and controlling *Salmonella.* If repeated *Salmonella* findings occur, a tightening of controls is considered. *Salmonella*-positive feed must not be marketed or transferred, and effective treatment must be carried out. Recall or withdrawal if *Salmonella* is detected or contamination that poses a risk to animal or human health is found. A ban is issued if the company fails to initiate a withdrawal or recall voluntarily. Sanctions can be imposed if the company has significant deficiencies in its quality system or fails to comply with an order or ban.
Estonia	Feed materials and final products at feed processing plants.	Final feed products are sampled and studied bacteriologically in 5% of the enterprises handling feedstuffs	Handling and selling of contaminated feed, placing such feed on the market and feeding such feed to animals are prohibited. The extent of the contamination, sources and routes of transmission are identified and then eliminated by thorough cleaning and disinfection.
	Feed materials and feed on farms, in the case of *Salmonella*-positive flocks.	From imported feedstuffs, official samples are taken from storage facilities during random inspection.	
Finland	Feed materials, production environment, final product at feed processing plants. Feed business operator sampling, official sampling for third country imports. The official controls are performed by the Finnish Food Authority.	Depends on production capacity.	Prohibition on using *Salmonella*-positive feed and feed materials. Suspension of feed production and distribution from *Salmonella*-positive feed plants. Tracing *Salmonella* contamination to the raw feed material and in production facilities. Enhancement of cleaning and disinfection and environmental sampling. Withdrawal of *Salmonella*-positive feed from farms.
France	Feed material and final product at feed processing plants. Official sampling for feed.	Sampling depends on feed producers' own-check procedures. Competent authority sampling examines 150–200 samples/year.	Destruction or adequate thermal treatment of *Salmonella*-contaminated feed batches.
Germany	Routine sampling of feed material and feed according to European and national legislation including feed business operator and official samplings and controls. Environmental and dust samples are additionally examined.	Sampling: Risk-based	Prohibition on using *Salmonella*-positive batches as feed.
Italy	Feed material and feed compounds at processing plants. Feed business operator samples based on their HACCP plans and competent authority (official) samples based on the national control program.	Sampling depends on feed producers' own-check procedures. Competent authority sampling examines about 100 samples of poultry feed/year for monitoring and 100 samples for surveillance (risk-based)	Adequate thermal treatment of *Salmonella*-positive batches. Epidemiological investigation to identify the source of contamination. Enhancement of cleaning and disinfection.
Norway	Feed materials with a high *Salmonella*-risk, and processing equipment and environmental samples where high-risk feed materials are handled.	Minimum sampling requirements are given in national legislation (FOR-2002-11-07-1290) Every 14 days or according to risk assessment. Quarterly for heat treated protein concentrate and cereals of domestic origin.	When *Salmonella* is detected in feed raw materials, the business can use the raw material after the product has undergone a sufficient process to eliminate the presence of *Salmonella.* The Norwegian Food Safety Authority decides the measures in each single case.
Poland	Feed materials, with particular emphasis on post-extraction meal and fishmeal, are indicated for testing. It is recommended, as a priority, to take samples of feed on large-scale farms and on laying hen farms and of feed materials derived from former food intended for feed purposes.	Annual National Official Control Plans call for 3040 samples per year, which are sampled by the competent authority in proportion to regional production and based on a risk analysis. In addition, sampling is undertaken for ad hoc actions.	Administrative actions to identify the source of non-compliance and to withdraw contaminated feeds from the market.
Portugal	Feed material and feed	Feed producers: according to own checks Official sampling: Risk-based	Prohibition on using *Salmonella*-positive batches as feed. Additional controls of preventive and corrective measures, including traceability of products.

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Table 1 (*continued*)

Country	Sample types	Sample frequency	Control actions
		Salmonella is tested in 20% of samples collected for the execution of several analytical determinations from feed mills (industrial or home-mixers), in plant-origin feed materials randomly sampled at producers' premises and in imports from third countries.	Withdrawal from the market for treatment or destruction. Enhanced surveillance of livestock holdings that received *Salmonella*-positive feed.
Serbia	All compound feed.	At least 7 samples if weight of feed is ≤ 2.5 tones. There is a formula for sample size if feed weight is higher, with maximum of 40 samples.	Prohibition of sale if *Salmonella*-positive. Additional feed treatment if *Salmonella*-positive.
Sweden	Feed materials and final product. Production environment samples. Feed business operator sampling.	Weekly sampling, minimum 5 samples along the production line, following points sampled: 1. Ready feed container (top) 2. Local dust from pellet cooler room 3. Pellet cooler (top) 4. Central aspiration (suction from). If there is only split aspiration, the aspiration is sampled in the raw material part of the facility 5. Raw material intake (elevator foot).	Suspension of feed production and distribution from *Salmonella*-positive feed plants. Tracing of *Salmonella* contamination. Enhancement of cleaning and disinfection and environmental sampling. Deliveries stopped, cleaning the facility, sampling after cleaning, more sampling according to the results from the initial sampling. Results must be *Salmonella*-negative before production can be started again.

NFSA – Norwegian Food Safety Authority.

carried out, and *Salmonella* must be absent in each sample weighing 25 g. In the case of positive results, control actions are applied to prevent contaminated feed from reaching animals (i.e., prohibition of sale, additional feed treatment, etc.).

The control actions for *Salmonella* implemented in feed among participating countries are presented in Table 1.

At farm level, EU-MSs are obligated to establish NCPs in poultry populations aiming to reduce the prevalence of *Salmonella* serovars considered to be most relevant for public health, i.e. the target serovars (Regulation (EC) No 2160/2003 (EC, 2003b)) to levels equal to 1% or below in breeding flocks of *Gallus gallus* (Regulation (EU) No 200/2010 (EC, 2010)), broilers (Regulation (EU) No 200/2012 (EC, 2012a)), and in breeding and fattening turkey flocks (Regulation (EU) No 1190/2012 (EC, 2012b)). Tables 2 and 3 summarise the controls implemented in the different countries for *Salmonella* surveillance in breeding and broiler flocks of *Gallus gallus*, and in turkey breeding and fattening flocks, respectively.

Food safety criteria (FSC) and process hygiene criteria (PHC) are implemented according to Regulation (EC) No 2073/2005 (EC, 2005c). At broiler abattoirs, per each sampling session, FBOs are obliged to randomly collect 25 g of pooled neck skin samples from 15 carcasses (three carcasses per batch of five different batches) after chilling and perform microbiological analyses as PHC. The sampling requirements and given thresholds are regulated and if the defined criterion (more than five samples positive for *Salmonella* out of 50 samples collected in ten consecutive sampling sessions) is not fulfilled, FBOs must take corrective actions like improving the slaughter hygiene, reviewing the origin of the animals or bolstering biosecurity measures on the farm (EC, 2005c). In meat cutting plants, samples are taken from fresh cut meat or from meat crush along the production line. If samples at abattoir or meat cutting level are *Salmonella*-positive, or at least positive for target serovars, the meat is destroyed, or processed using a treatment that ensures the elimination of*Salmonella.* Additional samples are then collected from the environment and from carcasses or from minced/-crushed meat, mechanically separated meat or meat preparations. The premises and equipment must be cleaned and disinfected. Additionally, Regulation (EC) No 2073/2005 (EC, 2005c) sets FSC for *Salmonella* in fresh poultry meat and poultry meat products placed on the market during their shelf-life. Samples are examined following the ISO 6579-1 standard (ISO, 2017), and *Salmonella* must be absent in 10 g or 25 g depending on the poultry meat product category. The only exception is for fresh meat for which Regulation (EC) No 2073/2005 (EC, 2005c) prescribes the absence of the target serovars (*S*. Enteritidis and *S*. Typhimurium including its monophasic variants). If *Salmonella*-positive, the products must be destroyed or recalled if they have already been placed on the market. National specific control actions can be set in the different EU-MSs.

3.2. *Country specific surveillance and control actions*

Some countries have NCPs for *Salmonella* in place which are based on EU legislation but are specified in national regulations or guidelines. In all countries, sampling is performed either by the FBO or representatives of the CA. In the following, country-specific control actions are presented per production level.

3.2.1. ***Feed level (Table 1)***

In addition to EU law, the official sampling of feed is specified in national legislation in Denmark (VEJ nr 9006 af 10/01/2023), Estonia (Estonian Regulation No 20; RT, 2014), Finland (FMAF, 2020), Norway (Norwegian Feed Act (FOR-2002-11-07-1290); NMTIF & NMAF, 2002) and Sweden (Anonymous, 2018a; 2022a, 2022b).

For the Nordic countries of Denmark, Finland, Norway and Sweden, sampling for *Salmonella* in feed is focused on feed materials with a high *Salmonella* risk, and on the processing equipment and environment. Additionally, in Finland, it is specified that high-risk feed imported from

Table 2
Summary of controls in the *Salmonella* surveillance systems for breeding flocks of *Gallus gallus* and broiler flocks in the studied countries.

Country	Type of flock	Target of program	Sampling level		
			Farm	Abattoir	Processing/Retail
Denmark	Breeding flocks	≤1% positive flocks	**Serovars targeted:** All serovars **Sample types**: Day-old chick transport crate swabs; Boot socks; **Sample frequency**: At day-old chick arrival; At 4 weeks of age and 2 weeks before laying; Every 2 weeks during laying	**Serovars targeted:** All serovars **Sample types:** Neck skin **Sample frequency**: From slaughterhouses slaughtering >1000 animals, 300 neck skin samples each weighing 1 g, pooled into subsamples of 60 g from one batch per week. From slaughterhouses slaughtering <1000 animals per day, 15 neck samples each approximately 10 g, pooled into 5 subsamples of 25 g from one batch every fifth day of slaughter	**Serovars targeted:** All serovars **Sample types**: Fresh meat, chilled meat, RTE **Sample frequency**: 200–300 depending on resources (official sampling)
	Broiler flocks		**Serovars targeted:** All serovars **Sample types**: Boot socks **Sample frequency**: At 15–21 days before slaughter, and at 7–10 days before slaughter, 5 pairs of boot swabs per flock. In both cases, for flocks with up to 500 animals, 5 samples can be pooled into 2 pools		
Estonia	Breeding flocks	≤1% positive flocks	**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , SH, SV, SI **Sample types**: Faecal, dust and litter samples and dead chicks; Boot socks **Sample frequency**: At day-old chick arrival; At 4 weeks of age and 2 weeks before laying; Every 2 weeks during laying	**Serovars targeted:** All serovars **Sample types**: Neck skin samples are taken from 3 broiler carcasses belonging to the same batch. **Sample frequency**: Continuous, weekly	**Serovars targeted:** All serovars **Sample types**: Fresh meat or fresh broiler meat cuttings, minimum, 25 g, FBO sampling **Sample frequency**: Calculated in accordance with production volumes of the establishment, considering the specifics of the work and the sampling results of previous years. The sampling at meat cutting plant is performed randomly and carried out each month. Meat products establishments - meat products are sampled regularly
	Broiler flocks		**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , **Sample types**: Boot socks **Sample frequency**: 2 pairs of boot socks, every flock 2–3 weeks before slaughter. Broiler flocks are also sampled on the initiative of the FBO (self-control) three weeks before slaughter. 1/3 of the flocks are tested officially, 2/3 of the flocks are tested by FBO		
Finland	Breeding flocks	≤1% positive flocks; ≤0.5% broiler meat	**Serovars targeted:** All serovars **Sample types**: 10 chick box linings pooled into 2 samples; 2 pairs of boot socks; 1 pair of boot socks and one environmental swab **Sample frequency**: At day-old chick arrival; At 4 weeks of age and 2 weeks before transport to laying farm; Every 2 weeks during laying. Official sampling and inspection once/year in rearing farm and twice per flock during laying period	**Serovars targeted:** All serovars **Sample types**: Neck Skin samples, FBO sampling **Sample frequency**: At least once/week; Small scale abattoirs: 100,000–150,000–6x/years, 10,000–100,000 – 3×/year, <10,000–1/year	**Serovars targeted:** All serovars **Sample types**: Meat or meat crush, minimum, 25 g, FBO sampling **Sample frequency**: Once per week on varying weekdays In small scale abattoirs, depending on production capacity
	Broiler flocks		**Serovars targeted:** All serovars **Sample types**: 2 pairs of boot socks; official sampling: 1 pair of boot socks and 1 dust or environmental swab **Sample frequency**: Every flock, 3 weeks before slaughter; official sampling and inspection once/year		
France	Breeding flocks	≤1% positive flocks	**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , SH, SV, SI, SK (Anonymous, 2022d) **Sample types**: Chick box lining; Boot socks **Sample frequency**: For national market only; At 4 weeks of age and 2 weeks before laying; Every 2 weeks during laying	**Serovars targeted:** SE, ST including MST 1,4, [5],12:i: , SK (Anonymous, 2022d) **Sample types**: Neck Skin samples, FBO sampling **Sample frequency**: At least once/week, less often for slaughterhouses <1 million kg/year	**Serovars targeted:** SE, ST including MST 1,4, [5],12:i: , SK (Anonymous, 2022d) **Sample types**: Meat or meat crush, minimum, 25 g, FBO sampling, surveillance control plan, official sampling **Sample frequency**: Depends on production capacity, 250 official samples in 2022 (C + S)
	Broiler flocks		**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , SK **Sample types**: 2 boot socks analysed as a pool **Sample frequency**: Every flock, 3 weeks before slaughter; official sampling and inspection once/year		

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Table 2 (*continued*)

Country	Type of flock	Target of program	Sampling level		
			Farm	Abattoir	Processing/Retail
Germany	Breeding flocks	≤1% positive flocks	**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: (Reg. (EU) No 200/2012, GeflSalmoV) **Sample types**: Day-old chick transport crate swabs; Boot socks **Sample frequency**: At day-old chick arrival; At 4 weeks of age and 2 weeks before laying; Every 2 weeks during laying	**Serovars targeted:** All serovars **Sample types**: Neck skin samples (Reg. (EC) No 2073/2005 **Sample frequency**: Each week; change of sampling day each week; can be reduced to fortnightly sampling if satisfactory results for 30 consecutive weeks (Reg. (EC) No 2073/2005. For calculating sampling plans, flocks with unknown *Salmonella* status and flocks positive for ST and SE have to be considered. Sampling by FBO following sampling scheme in Reg. (EC) No 2073/2005 Check by CA	**Serovars targeted:** fresh meat: SE, ST; Products: all serovars **Sample types**: Fresh poultry meat (25 g of at least 5 samples per batch) Meat products **Sample frequency**: Each week; change of sampling day each week; can be reduced to fortnightly sampling if satisfactory results for 30 consecutive weeks (Reg. (EC) No 2073/2005. Sampling by FBO Check by CA. For zoonosis monitoring (Dir. 2003/99/EC) calculated sampling plan, broilers included every 2 years (pooled caecum, neck skin and fresh broiler meat)
	Broiler flocks		**Serovars targeted:** All serovars **Sample types**: Boot socks (Reg. (EU) No 200/2012, GeflSalmoV, 2009) + QS[a]: day-old chicks at beginning of fattening: dust samples at hatchery **Sample frequency**: FBO: all broiler flocks 3 weeks before slaughter + QS[a]: Beginning of fattening: all flocks		
Italy	Breeding flocks	≤1% positive flocks	**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , SH, SV, SI **Sample types**: Day-old chick transport crate swabs; Boot sock, dust and faecal samples **Sample frequency**: FBOs: At day-old chick arrival; At 4 weeks of age. and 2 weeks before laying; Every 3 weeks during laying CAs: All flocks, twice during the production cycle, at the beginning and toward the end of the cycle	**Serovars targeted:** All serovars **Sample types**: Neck skin samples, collected by FBOs/same samples can be collected also by CA **Sample frequency**: FBOs: frequency of sampling is defined by the own check programs, each week; change of sampling day each week; the sampling frequency can be reduced to every two weeks if satisfactory results are obtained for 30 consecutive weeks (Reg. (EC) No 2073/2005). Moreover, the frequency can be reduced according to the capacity of the slaughterhouse (41/CSR, 2015) CA: 1) collection of at least 49 random samples in each slaughterhouse annually, or a reduced number of samples in small slaughterhouses based on a risk evaluation; or 2) collection of all information on *Salmonella*-positive samples from own-checks carried out by the FBOs EC, 2019(Reg. (EU) 2019/627)	**Serovars targeted:** fresh meat: SE, ST; including MST 1,4, [5],12:i: ; Meat preparation – minced meat -meat products: all serovars **Sample types**: Fresh poultry meat, meat preparation, minced meat, meat products **Sample frequency**: FBOs: frequency of sampling is defined by the own check programs, each week; change of sampling day each week; the sampling frequency can be reduced to every two weeks if satisfactory results are obtained for 30 consecutive weeks (Reg. (EC) No 2073/2005). CA: the number of samples to be collected is defined at national level. SE, ST including MST 1,4, [5],12:i: , must be absent in 25 g of fresh poultry meat. In poultry minced meat, meat preparations and meat products to be eaten cooked all *Salmonella* serovars must be absent in 25 (212/CSR, 2016)
	Broiler flocks		**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , **Sample types**: Boot socks; dust swab **Sample frequency**: FBOs: every flock is sampled 3 weeks before slaughter; CA: one flock/year on the 10% of the farms with more than 5000 animals		
Norway	Breeding flocks	≤1% positive flocks (estimated prevalence below 0.5% in examined populations for all years the surveillance programme has run)	**Serovars targeted:** All serovars **Sample types**: Transport crate liners or swabs; booth socks; dust (cloth); **Sample frequency**: At day-old chick arrival; At 4 weeks of age and 2 weeks before laying; Every 2 weeks during laying	**Serovars targeted:** All serovars **Sample types**: Neck skin samples, FBO sampling **Sample frequency**: Once a week rotating day. Reduced to every 14 days if satisfactory results from previous 30 weeks (in accordance with Reg. (EC) 2073/2005).	**Serovars targeted:** All serovars **Sample types**: Meat and minced meat, FBO sampling **Sample frequency**: Once a week rotating day. Reduced to every 14 days if satisfactory results from previous 30 weeks (in accordance with Reg. (EC) 2073/2005).
	Broiler flocks	≤1% positive flocks. (estimated prevalence below 0.5% in examined populations for all years the surveillance programme has run)	**Serovars targeted:** All serovars **Sample types**: Boot socks; dust (cloth). **Sample frequency**: Every flock sampled by FBOs 10–19 days prior to slaughter CA: Once a year per holding.		
Poland	Breeding flocks	≤1% positive flocks	**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , SH, SV, SI **Sample types**: Day-old chick transport crate swabs; Boot socks **Sample frequency**: At day-old chick arrival; At 4 weeks of age and 2 weeks before laying; Every 2 weeks during laying	**Serovars targeted:** All serovars **Sample types**: Neck skin samples **Sample frequency**: Once a week, rotating day is mandatory, food business operator conducts sampling, and verification samples can be collected by the CA from the same lot. Can be reduced to every 14 days on FBO request if results have been satisfactory for 30 consecutive weeks	**Serovars targeted:** All serovars **Sample types**: Fresh meat, 25 g, food business operator sampling and verification samples collected by the CA from the same lot. Fresh meat, minced meat, raw **Sample frequency**: Once a week rotating day. Can be reduced to every 14 days on FBO request if results have been satisfactory for 30 consecutive weeks
	Broiler flocks		**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , **Sample types**: Boot socks **Sample frequency**: 14 days prior to slaughter		

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Table 2 (*continued*)

Country	Type of flock	Target of program	Sampling level		
			Farm	Abattoir	Processing/Retail
Portugal	Breeding flocks	≤1% positive flocks	**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , SH, SV, SI **Sample types**: Day-old chick transport crate swabs; Boot socks **Sample frequency**: At day-old chick arrival; At 4 weeks of age and 2 weeks before laying; Every 2 weeks during laying	**Serovars targeted:** All serovars **Sample types**: Neck skin samples, 10 g from 15 animals, 5 pools of 25 g, FBO and official sampling **Sample frequency**: Weekly Frequency can be reduced to fortnightly if satisfactory results have been obtained for 30 consecutive weeks (Reg. (EC) No 2073/2005).	**Serovars targeted:** Fresh meat SE, ST including MST 1,4, [5],12:i: , Meat preparations – all serovars **Sample types**: Fresh meat, minced meat, meat preparations and RTE **Sample frequency**: Weekly Frequency can be reduced to fortnightly if satisfactory results have been obtained for 30 consecutive weeks (Reg. (EC) No 2073/2005).
	Broiler flocks		**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , **Sample types**: Boot socks **Sample frequency**: Every flock, 3 weeks before slaughter; Official sampling once/year in 10% of flocks		
Serbia	Breeding flocks	≤1% positive flocks (with 95% confidence level)	**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , SH, SV, SI **Sample types**: Pooled sample of faeces - number of faecal samples depends on flock size (e.g. 250 birds: 200 samples, more than 1000 birds: 300 samples) or boot socks (e.g. 5 pairs, each covering/representing 20 % of floor surface) **Sample frequency**: Every 2 weeks (sampling done by food business operator)	**Serovars targeted:** All serovars **Sample types**: Neck skin samples, 10 g from 15 animals, 5 pools of 25 g, FBO sampling **Sample frequency**: Weekly	**Serovars targeted:** All serovars **Sample types**: Meat preparations, minced meat, meat products. **Sample frequency**: Weekly. Frequency can be reduced to fortnightly if satisfactory results have been obtained for 30 consecutive weeks.
	Broiler flocks		**Serovars targeted:** SE, ST **Sample types**: Pooled sample of faeces from each flock, number of faecal samples depends on flock size, sampling done by food business operator and/or as official sampling **Sample frequency**: Once/year in farms with >5000 animals or whenever needed according to OV		
Sweden	Breeding Flocks	≤1% positive flocks	**Serovars targeted:** All serovars **Sample types**: Day-old chick transport crate swabs; Boot socks **Sample frequency**: At day-old chick arrival; At 4 weeks of age and 2 weeks before laying; Every 2 weeks during laying	**Serovars targeted:** All serovars **Sample types**: Neck skin samples, 10 g; **Sample frequency**: number of samples related to the slaughter volume, to detect a prevalence of 0.1%	**Serovars targeted:** All serovars **Sample types**: In cutting meat residues are sampled along the cutting line, approximately 1000 samples per year Can be different kinds of foods, including poultry at retail. Up to 10 samples are allowed to be pooled into a single sample **Sample frequency**: 500–1000 samples per year in official sampling by local authorities at food enterprises, other than cutting plants. These samples are analysed mainly using NMKL (nr 71:1999).
	Broiler Flocks	≤1% positive flocks Prevalence of 0.1% with 95% confidence level in poultry carcasses at a national level	**Serovars targeted:** All serovars **Sample types**: Boot swabs, or faeces swabs **Sample frequency**: Within 3 weeks before slaughter		

SE – *Salmonella* Enteritidis, ST – *Salmonella* Typhimurium, MST – Monophasic variant of *Salmonella* Typhimurium, SH – *Salmonella* Hadar, SV, *Salmonella* Virchow, SI – *Salmonella* Infantis, SK – *Salmonella* Kentucky. RTE - Ready-to-eat; FBO – Food Business Operator; CA – Competent Authority; OV – Official Veterinarian; QS – private German program for different production stages and products along the food chain; NMKL = Nordic-Baltic Committee on Food Analysis, https://www.nmkl.org.

Table 3
Summary of controls in the *Salmonella* surveillance systems in turkey breeding flocks and fattening turkey flocks in the studied countries.

Country	Type of flock	Target of program	Sampling level		
			Farm	Abattoir	Processing/Retail
Denmark[a]	Breeding flocks	≤1% positive flocks	**Serovars targeted:** All serovars **Sample types**: NA **Sample frequency**: NA	NA	NA
	Fattening flocks		**Serovars targeted:** All serovars **Sample types**: Boot swabs **Sample frequency**: 2 pairs of boot swabs, analysed individually. At ≤21 days before slaughter		
Estonia[b]	NA	NA	**Serovars targeted:** NA **Sample types**: NA **Sample frequency**: NA	**Serovars targeted:** NA **Sample types**: NA **Sample frequency**: NA	**Serovars targeted:** All serovars (imported turkey meat) **Sample types**: Samples are taken at meat processing plants (handling of imported turkey meat). Fresh meat, meat preparations and meat products are sampled at meat processing plants or at retail, also at border inspection posts **Sample frequency**: Sampling is random and is performed in the frame of official control. Targeted sampling is performed in the case of suspicion and consumer complaints
Finland[c]	Breeding flocks	≤1% positive flocks; ≤0.5% meat	**Serovars targeted:** All serovars **Sample types**: 10 poult box linings; 2 pairs of boot socks; 1 pair of boot socks and one environmental swab **Sample frequency**: At day-old poult arrival; At 4 weeks of age and 2 weeks before transport to laying farm; Every 2 weeks during laying. Official sampling and inspection once/year in rearing period and once/each flock during laying period	**Serovars targeted:** All serovars **Sample types**: Neck skin samples, FBO sampling **Sample frequency**: At least once/week; Small scale abattoirs: 100,000–150,000: 6×/years, 10,000–100,000: 3×/year, <10,000: 1/year	**Serovars targeted:** All serovars **Sample types**: Meat or meat crush, minimum, 25 g, FBO sampling **Sample frequency**: Once per week on varying weekdays. In small scale abattoirs, depending on production capacity
	Fattening flocks		**Serovars targeted:** All serovars **Sample types**: 2 pairs of boot socks; official sampling: one pair of boot socks and one dust or environmental swab **Sample frequency**: Every flock, 3 weeks before slaughter; official sampling and inspection once/year		
France	Breeding flocks	≤1% positive flocks	**Serovars targeted:** SE, ST, SK **Sample types**: Poult box lining; Boot socks **Sample frequency**: At day-old poult arrival; At 4 weeks of age and 2 weeks before laying; Every 2 weeks during laying	**Serovars targeted:** SE, ST, SK **Sample types**: Neck skin samples, FBO sampling **Sample frequency**: At least once/week, less often for slaughterhouses <1 million kg/year	**Serovars targeted:** SE, ST, SK **Sample types**: Meat or meat crush, minimum, 25 g, FBO sampling, surveillance control plan, official sampling **Sample frequency**: Depends on production capacity, 250 official samples in 2022
	Fattening flocks		**Serovars targeted:** SE, ST, SK **Sample types**: 2 boot socks analysed as a pool **Sample frequency**: Every flock, 3 weeks before slaughter; official sampling and inspection once/year		
Germany[d]	Breeding flocks	≤1% positive flocks	**Serovars targeted:** SE, ST (Reg. (EU) No 1190/2012; GeflSalmoV) **Sample types**: Poult box lining; Boot socks; **Sample frequency**: At day-old poult arrival; At 4 weeks of age and 2 weeks before laying; Every 2 weeks during laying	**Serovars targeted:** All serovars **Sample types**: Neck skin samples **Sample frequency**: Same as for broilers	**Serovars targeted:** Retail level: fresh: SE, ST. Products: All serovars **Sample types**: Fresh, meat products **Sample frequency**: Same as for broilers
	Fattening flocks		**Serovars targeted:** SE, ST (Reg. (EU) No 1190/2012; GeflSalmoV) **Sample types**: Boot socks (GeflSalmoV, Reg. (EU) No		

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Table 3 (*continued*)

Country	Type of flock	Target of program	Sampling level		
			Farm	Abattoir	Processing/Retail
			1190/2012) **Sample frequency**: FBO: all flocks 3 weeks before slaughter. CA: each year at least 1 flock in 10% of farms with >500 turkeys		
Italy	Breeding flocks	≤1% positive flocks	**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , **Sample types**: Day-old poults transport crate swabs Boot socks; dust swab – faecal samples **Sample frequency**: FBOs: At day-old poult arrival; At 4 weeks of age; 2 weeks before laying; Every 4 weeks during laying CAs: Once a year in every flock (between 30 and 45 weeks)	**Serovars targeted:** All serovars **Sample types**: Neck skin samples, collected by FBOs/same samples can also be collected by CAs **Sample frequency**: FBOs: frequency of sampling is defined by the own check programs, each week; change of sampling day each week; the sampling frequency can be reduced to every two weeks if satisfactory results are obtained for 30 consecutive weeks (Reg. (EC) No 2073/2005). Moreover, the frequency can be reduced according to the capacity of the slaughterhouse (41/CRS, 2015) CA: 1) collection of at least 49 random samples in each slaughterhouse annually, or a reduced number of samples in small slaughterhouses based on a risk evaluation; or 2) collection of all information on *Salmonella*-positive samples from own-checks carried out by the FBOs (Reg. (EU) 2019/627)	**Serovars targeted:** fresh meat: SE, ST; including MST 1,4, [5],12:i: ; Meat preparation – minced meat -meat products: all serovars (Reg. (EC) No 2073/2005) **Sample types:** Fresh poultry meat, meat preparation, minced meat, meat products **Sample frequency**: FBOs: frequency of sampling is defined by the own check programs, each week; change of sampling day each week; the sampling frequency can be reduced to every two weeks if satisfactory results are obtained for 30 consecutive weeks (Reg. (EC) No 2073/2005.) CA: the number of samples to be collected is defined at national level. SE, ST including MST 1,4, [5],12:i: must be absent in 25 g of fresh poultry meat. In poultry minced meat, meat preparations and meat products to be eaten cooked all *Salmonella* serovars must be absent in 25 g (212/CSR, 2016)
	Fattening flocks		**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , **Sample types**: Boot socks; dust swab **Sample frequency**: FBOs: every flock is sampled 3 weeks before slaughter; CA: one flock/year on the 10% of the farms with more than 500 animals		
Norway	Breeding flocks	≤1% positive flocks (estimated prevalence below 0.5% in examined populations for all years the surveillance programme has run)	**Serotypes targeted:** All serotypes **Sample types**: Transport crate liners or swabs; boot swabs; dust (cloth) **Sample frequency**: At day-old chick arrival; At 4 weeks of age and 2 weeks before laying; Every 2 weeks during laying	**Serotypes targeted:** All serotypes **Sample types**: Neck skin samples, FBO sampling **Sample frequency**: Once per week	**Serotypes targeted:** All serotypes **Sample types**: Meat or meat crush, FBO sampling **Sample frequency**: Once per week and can be reduced depending on size of plants.
	Fattening flocks		**Serotypes targeted:** All serotypes **Sample types**: Boot socks, dust (cloth) **Sample frequency**: Every flock sampled by FBOs 10–19 days prior to slaughter. CA: once a year per holding		
Poland	Breeding flocks	≤1% positive flocks	**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , **Sample types**: 10 poult boxes lining; 10 swabs from chick boxes, dead poults, boot socks (farmer) **Sample frequency**: Day-old poults; at 4 weeks of age, 2 weeks before laying; every 3 weeks during laying	**Serovars targeted:** All serovars **Sample types**: Neck skin samples (FBO) **Sample frequency**: Once per week	**Serovars targeted:** All serovars **Sample types**: Fresh meat, minced meat, meat products (FBO) **Sample frequency**: Once per week; the frequency can be reduced in small production plants
	Fattening flocks		**Serovars targeted:** SE, ST, MST **Sample types**: Boot socks (FBO) **Sample frequency**: 3 weeks before slaughter (CA can allow the samples to be collected 6 weeks before slaughter in the case of organic farming)		
Portugal[c]	Breeding flocks	NA	NA	**Serovars targeted:** All serovars **Sample types**: Neck skin samples, 10 g from 15 animals, 5 pools of 25 g, food business operator and official sampling **Sample frequency**: Weekly frequency can be reduced to fortnightly if satisfactory results have been obtained for 30 consecutive weeks Reg. (EC) No 2073/2005.)	**Serovars targeted:** fresh meat SE, ST including MST 1,4, [5],12:i: , Meat preparations: all serovars **Sample types**: Fresh meat, minced meat, meat preparations **Sample frequency**: Weekly frequency can be reduced to fortnightly if satisfactory results have been obtained for 30 consecutive weeks Reg. (EC) No 2073/2005.)
	Fattening flocks	≤1% positive flocks	**Serovars targeted:** SE, ST including MST 1,4, [5],12: i: , **Sample types**: Boot socks, FBO sampling, Boot socks or one pair of boot socks and dust sample (100 g), official sampling **Sample frequency**: Every flock, 3 weeks before slaughter; FBO and official sampling		

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Table 3 (*continued*)

Country	Type of flock	Target of program	Sampling level		
			Farm	Abattoir	Processing/Retail
Serbia	Breeding flocks	≤1% positive flocks (with 95% confidence level)	**Serovars targeted:** SE, ST **Sample types**: Pooled sample of faeces - number of faecal samples depends on flock size (e.g. 250 birds: 200 samples, more than 1000 birds: 300 samples) or boot socks (e.g. 5 pairs, each covering/representing 20% of floor surface) **Sample frequency**: At least once every 3 weeks	**Serovars targeted:** All serovars **Sample types**: Neck skin samples, 10 g from 15 animals, 5 pools of 25 g, food business operator sampling **Sample frequency**: Weekly	**Serovars targeted:** All serovars **Sample types**: Meat preparations, minced meat, meat products **Sample frequency**: Weekly. Frequency can be reduced to fortnightly if satisfactory results have been obtained for 30 consecutive weeks.
	Fattening flocks	≤1% positive flocks (with 95% confidence level)	**Serovars targeted:** SE, ST **Sample types**: Pooled sample of faeces from each flock, number of faecal samples depends on flock size, sampling done by food business operator and/or as official sampling **Sample frequency**: Once/year in farms with >500 animals or whenever needed according to OV		
Sweden[f]	Breeding flocks	≤1% positive flocks	**Serovars targeted:** All serovars **Sample types**: Day-old chick transport crate swabs; Boot socks **Sample frequency:** At day-old chick arrival; At 4 weeks of age and 2 weeks before laying; Every 2 weeks during laying	**Serovars targeted:** All serovars **Sample types**: Neck skin samples, 10 g; **Sample frequency**: number of samples related to the slaughter volume, to detect a prevalence of 0.1%	**Serovars targeted:** All serovars **Sample types**: can be different kind of food, including turkey **Sample frequency**: 500–1000 samples per year in official sampling by local authorities at food enterprises, other than cutting plants. These samples are analysed mainly using NMKL (NMKL, 1999).
	Fattening flocks	≤1% positive flocks (prevalence of 0.1% with 95% confidence level in poultry carcasses at a national level)	**Serovars targeted:** All serovars **Sample types:** Boot swabs, or faeces swabs **Sample frequency:** Within 3 weeks before slaughter		

SE – *Salmonella* Enteritidis, ST – *Salmonella* Typhimurium, MST – Monophasic variant of *Salmonella* Typhimurium, SH – *Salmonella* Hadar, SV, *Salmonella* Virchow, SI – *Salmonella* Infantis.
NA – not applicable, FBO – Food Business Operator; CA – Competent Authority; NMKL = Nordic-Baltic Committee on Food Analysis, https://www.nmkl.org.

[a] Denmark: Turkey breeding & fattening flocks - they are mostly slaughtered abroad.
[b] No turkey flocks in Estonia.
[c] Finland: target of the program for meat ≤0.5%.
[d] QS – private German program for different production stages and products along the food chain.
[e] No turkey breeding flocks in Portugal.
[f] All species of poultry are included in the same program in Sweden.

Table 4
Five most commonly detected *Salmonella* serovars in broilers in the studied countries in the years 2017–2021 (from farm- and meat-level controls).

Country	2017	2018	2019	2020	2021
Denmark	Farm level (Anonymous, 2018c): MST 4,5,12:i: MST 4,12:i: *S.* Give *S.* Derby *S.* Yoruba Abattoir/retail level (Anonymous, 2018b): RTE: no positive samples	Farm level (Anonymous, 2019): ST MST 4,5,12:i: MST 4,12:i: SE *S.* Wangata *S.* Seftenberg Abattoir/retail level (Anonymous, 2019): Products made from poultry, intended to be cooked: *Salmonella* (unspecified)	Farm level (Anonymous, 2020a): MST 4,5,12:i: MST 4,12:i: *S.* Derby SI *S.* Newport Abattoir/retail level (Anonymous, 2020): Products made from poultry, intended to be cooked: none	Farm level (Anonymous, 2021): ST MST 4,5,12:i: MST 4,12:i: *S.* Aarhus *S.* Derby SE Abattoir/retail level (Anonymous, 2021): Products made from poultry, intended to be cooked: none	Farm level (Anonymous, 2022c) MST 4,5,12:i: MST 4,12:i: ST *S.* Derby *S.* Newport Abattoir/retail level (Anonymous, 2022c): Products made from poultry, intended to be cooked: none
Estonia	Farm level: *S.* Derby Abattoir/meat cutting plant level: No positive samples (AFB, 2023)	Farm level: No positive flocks Abattoir/meat cutting plant level: No positive samples (AFB, 2023)	Farm level: ST SI Abattoir/meat cutting plant level: No positive samples (AFB, 2023)	Farm level: No positive flocks Abattoir/meat cutting plant level: No positive samples (AFB, 2023)	Farm level: No positive flocks Abattoir/meat cutting plant level: No positive samples (AFB, 2023)
Finland	Farm level: *S.* Livingstone Abattoir/meat cutting plant level: No positive samples	Farm level: No positive flocks Abattoir/meat cutting plant level: No positive samples	Farm level: *S.* Bredeney Abattoir/meat cutting plant level: No positive samples	Farm level: *S.* Infantis Abattoir/meat cutting plant level: No positive samples	Farm level: No positive flocks Abattoir/meat cutting plant level: No positive samples
France	ND	ND	Farm level: *S.* Montevideo *S.* Livingstone ST *S.* Napoli SE Abattoir/meat cutting level: ND	Farm level: *S.* Montevideo *S.* Livingstone ST SE *S.* Napoli Abattoir/meat cutting level: ND	Farm level: *S.* Montevideo *S.* Livingstone ST SE *S.* Mbandaka Abattoir/meat cutting level: ND
Germany[a,b]	Farm level (BfR, 2020a): SE ST Abattoir/retail level (Hartung et al. (2021): SI *S.* Paratyphi B var. Java SE *S.* Indiana *S.* Newport *S.* Heidelberg O:5	Farm level (BfR, 2020b): SE ST Abattoir/retail level (zoonosis monitoring) BVL, 2019): SI *S.* Paratyphi B ST *S.* Bareilly *S.* Indiana	Farm level (BfR, 2020c): SE ST Abattoir/retail level: ND	Farm level (BfR, 2023a): SE ST Abattoir/retail level (zoonosis monitoring) (BVL, 2021): SI *S.* Paratyphi B *S.* Subspecies I rough	Farm level (BfR, 2023b): ST SE Abattoir/retail level: ND
Italy	Farm level: SI *S.* Thompson *S.* Mbandaka *S.* Livingstone Abattoir level: ND	Farm level: SI *S.* Mbandaka *S.* Thompson *S.* Livingstone *S.* Kedougou Abattoir level: ND	Farm level: SI *S.* Thompson *S.* Mbandaka *S.* Senftenberg *S.* Livingstone Abattoir level: ND	Farm level: SI *S.* Mbandaka *S.* Thompson *S.* Livingstone *S.* Kedougou Abattoir level: SI *S.* Hadar *S.* Blockley *S.* Bredeney *S.* Kentucky	Farm level: SI *S.* Mbandaka *S.* Livingstone *S.* Thompson *S.* Senfteberg Abattoir level: SI *S.* Livingstone *S.* Mbandaka
Norway	Farm level: No positive flocks Abattoir level: ND	Farm level: No positive flocks Abattoir level: ND	Farm level: *S.* Give Abattoir level: ND	Farm level: ST Abattoir level: ND	Farm level: No positive flocks Abattoir level: ND
Poland	Farm level: SI SE	Farm level: SE SI	Farm level: SE SI	Farm level: NP	Farm level: SE SI

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Table 4 (*continued*)

Country	2017	2018	2019	2020	2021
	S. Newport *S.* Indiana *S.* IV, group O:7	*S.* Newport *S.* Kentucky *S.* Mbandaka	*S.* Newport *S.* Thompson *S.* Kentucky	Abattoir level: ND	*S.* Newport *S.* Mbandaka *S.* group O:8
	Abattoir level: ND	Abattoir level: ND	Abattoir level: ND		Abattoir level: ND
Portugal	Farm level: *S.* Havana MST 4,5,12,i: *S.* Cerro *S.* Lexington	Farm level: *S.* Havana *S.* Anatum *S.* Mbandaka SI *S.* Cerro/*S.* Lexington	Farm level: *S.* Newport S. Tomegbe *S.* Anatum MST 4, [5],12:i: *S.* Bardo	Farm levvel: SE *S.* Duesseldorf MST 4, [5],12:i- *S.* Tomegbe MST 4,12:i-	Farm level: MST 4, [5],12:i: SE *S.* Newport ST *S.* Bardo
	Abattoir/retail level: ST	Abattoir/retail level: SE	Abattoir/retail level: Not detected	Abattoir/retail level: Not detected	Abattoir/retail level: *Salmonella* (unspecified)
Serbia	ND	ND	ND	Farm level: ND	Farm level: ND
				Abattoir/retail level: *Salmonella* (unspecified)	Abattoir/retail level: *Salmonella* (unspecified)
Sweden	Farm level (SVA, 2017): ST	Farm level (SVA, 2018): *S.* Mbandaka ST	Farm level (SVA, 2019): *S.* Bukavu *S.* Reading	Farm level (SVA, 2020): No positive flocks	Farm level (SVA, 2021): SE *S.* Tennesee
	Abattoir/cutting level (SVA, 2017): no positive samples			Abattoir/cutting level (SVA, 2020): no positive samples	
		Abattoir/cutting level (SVA, 2018): no positive samples	Abattoir/cutting level (SVA, 2019): no positive samples		Abattoir/cutting level (SVA, 2021): no positive samples

SE – S. Enteritidis, ST – S. Typhimurium, MST – monophasic variant of S. Typhimurium, SH–S. Hadar, SI–S. Infantis, SV–S. Virchow.
RTE – Ready-to-eat; ND – no data.
[a] At farm level only control programs for S. Enteritidis and S. Typhimurium in place for broilers. Serotyping top 5 only in *Gallus gallus* flocks.
[b] Sampling regarding zoonosis monitoring (Dir. 2003/99/EC) broilers only included in 2018, 2020 (pooled caecum samples, neck skin, fresh broiler meat).

third countries is sampled in accordance with the Finnish control plan (FMAF, 2020). In Sweden, where *Salmonella* control in feed goes back to 1950s, the feed business operator must sample the feed raw materials used even when they are not listed by the national legislation; this is to allow hazards to be identified by the feed business operator based on empirical risk analysis (Anonymous, 2018a).

For the southern European countries of Italy and Portugal, NCPs are specified by legislation, and in Portugal, all feed must be *Salmonella*-free (Portuguese Decree-Law No 105/2003).

In the two western European countries, France and Germany, no specific national regulations are set for feed control regarding *Salmonella*, but private programs exist. In France, the private organisation Oqualim collects the results of feed business operator controls on *Salmonella* in feed, which are transmitted on a voluntary basis; this collecting system covers almost 95% of the national feed production and gathers more than 700 *Salmonella* results on poultry and turkey feed yearly (ANSES, 2018). In Germany, private surveillance programs are implemented in the national, private 'Qualität und Sicherheit' (QS) scheme. Approximately 90% of poultry producers in Germany, excluding mainly small holdings, are participants in the QS scheme. The guidelines cover official samplings, but also provide some additional samplings and controls to be applied by participants in this scheme (Anonymous, 2023a).

In the non-EU country of Serbia, no specifics about any corrective actions applied after *Salmonella*-positive findings in feed are laid down, and there is no guideline that specifies how to deal with such findings. The test results are not publicly available.

3.2.2. *Farm level* (*Tables 2–5*)

In the Nordic countries studied, farm level control programs were set in the 1990s, focusing on lowering the prevalence on farms and intending to ensure that poultry sent to slaughter and the products of poultry meat are free from *Salmonella*. The Danish *Salmonella* control program for broilers was first launched in 1996 with the aim to lower the prevalence on farms (to <5%), but it was revised in 2003 with the aim to achieve complete freedom of *Salmonella* in broiler production to attain the "*Salmonella* Guarantee". The program is based on a top-down eradication approach, where infected breeding flocks are culled (by industrial initiative) or are subject to logistic slaughter and heat treatment of the meat (Anonymous, 2020a,b,c,d,e). In addition, the broiler flocks are tested twice before slaughter (Anonymous, 2018b). Vaccination is not used in Denmark. The Finnish *Salmonella* control program for poultry, covering broiler and turkey chains from breeders, hatcheries, and commercial farms, started in 1995, and is based on the Commission Decision 94/968/EC (EC, 1994). Prior to the official control program, *Salmonella* was voluntarily controlled in cooperation between the authorities and food producers including primary production. Vaccination and antimicrobial treatment against *Salmonella* is prohibited. National control actions regarding sampling and outbreak investigations are regulated in national legislation (FMAF, 2021a, Finnish Animal Diseases Act 76/2021). In Norway, the official *Salmonella* control program for poultry started in 1995 and is based on the EFTA SURVEILLANCE AUTHORITY DECISION No 68/95/COL. The program aims to ensure that Norwegian food-producing animals and the food products of animal origin are virtually free from *Salmonella*, to provide the reliable documentation of the prevalence of *Salmonella* in the livestock populations and their products, and to prevent an increased occurrence of human salmonellosis in Norway. Vaccination against *Salmonella* is prohibited ((EC, 2003b). In Sweden, the national Zoonosis Law (Anonymous, 1999a) and Zoonosis Regulation (Anonymous, 1999b) set out the basic rules for *Salmonella* control at farm level for all types of poultry. The national legislation rules the actions when there is a suspicion of or ascertained *Salmonella* presence in living animals (Anonymous, 2014) and regarding basic hygienic prophylaxis for biosecurity in living animals (Anonymous, 2013). Surveillance aims to ensure that animals sent to slaughter and animal products are free from *Salmonella* (SVA, 2021). Both the compulsory program (breeding flocks with more than 250 birds) and the voluntary programs have been in place for more than the

Table 5
Five most commonly detected *Salmonella* serovars from fattening turkeys in the studied countries in the years 2017–2021 (from farm- and meat-level controls).

Country	2017	2018	2019	2020	2021
Denmark[a]	Farm level (Anonymous, 2018b):	Farm level (Anonymous, 2019):	Farm level (Anonymous, 2020a):	Farm level (Anonymous, 2021):	Farm level (Anonymous, 2022c):
	No positive flocks	No positive flocks	No positive flocks	No positive flocks	No positive flocks
		Abattoir level	Abattoir level	Abattoir level[d]	Abattoir level:
	Abattoir level	NA	NA	NA	NA
	NA				
Estonia[b]	NA	NA	NA	NA	NA
Finland	Farm level:	Farm level:	Farm level:	Farm level:	Farm level:
	No positive flocks	No positive flocks	No positive flocks	No positive flocks	No positive flocks
	Abattoir/meat cutting plant level:	Abattoir/meat cutting plant level:	Abattoir/meat cutting plant level:	Abattoir/meat cutting plant level:	Abattoir/meat cutting plant level:
	No positive samples	No positive samples	No positive samples	No positive samples	No positive samples
France	ND	ND	Farm level:	Farm level:	Farm level:
			S. Senftenberg	MST 4, [5],12:i:	*S.* Agona,
			MST 4, [5],12:i:	*S.* Napoli	MST 4, [5],12:i:
			S. Newport	SH	*S.* Stanley
			S. Napoli	ST	SE
			S. Saintpaul	SE	ST
			Abattoir/retail level:	Abattoir/retail level:	Abattoir/retail level:
			ND	ND	ND
Germany[c,d]	Farm level (BfR, 2020a):	Farm level (BfR, 2020b):	Farm level (BfR, 2020c):	Farm level (BfR, 2023a)	Farm level (BfR, 2023b):
	ST	ST	ST	ST	ST
	SE	SE		SE	SE
	Hartung et al. (2021):	Abattoir/retail level (zoonosis monitoring) (BVL, 2019):	Abattoir/retail level:	Abattoir/retail level (zoonosis monitoring) (BVL, 2021):	
	ST	MST 4, [5],12:I:	ND	*S.* Senftenberg	
	SE	*S.* Agona		MST	
	S. Coeln	*S.* Subspecies I		*S.* Schwarzengrund	
	MST 4, [5],12:I:	*S.* Hadar		*S.* Kottbus	
	SH	*S.* Newport		*S.* Brandenburg	
	S. Anatum				
	S. Cubana				
	S. Saintpaul				
	Abattoir/Retail level (additional official reporting) (Hartung et al., 2021):				
	Turkey meat				
	SH				
	SI				
	S. Kottbus				
	S. Agona				
	S. Bredney				
Italy	Farm level:	Farm level:	Farm level:	Farm level:	Farm level:
	ND	SI	SI	*S.* Anatum	*S.* Anatum
		S. Kentucky	*S.* Newport	SI	*S.* Agona
		S. Seftenberg	*S.* Haifa	*S.* Newport	SI
		S. Newport	*S.* Agona	*S.* Agona	*S.* Newport
		S. Haifa	*S.* Saintpaul	*S.* Haifa	*S.* Saintpaul
	Abattoir level:				
	ND	Abattoir level:	Abattoir level:	Abattoir level:	Abattoir level:
		ND	ND	ND	ND
Norway	Farm level:	Farm level:	Farm level:	Farm level:	Farm level:
	No positive flocks	ST	*S.* Agona	No positive flocks	No positive flocks
	Abattoir level	Abattoir level	Abattoir level	Abattoir level	Abattoir level
	ND	ND	ND	ND	ND
Poland	Farm level:	Farm level:	Farm level:	Farm level:	Farm level:
	S. Kentucky	*S.* Kentucky	*S.* Kentucky	NA	*S.* Anatum
	S. Newport	SE	*SE*		*S.* Derby
	S. Saintpaul	*S.* group O:8	*S.* Lagos	Abattoir/retail level:	SE
	S. Agona	ST	*S.* Anatum	ND	*S.* Infantis
	S. Chester	*S.* Heidelberg	*S.* Derby		*S.* Kentucky
	Abattoir/retail level:	Abattoir/retail level:	Abattoir/retail level:		Abattoir/retail level:
	ND	ND	ND		ND
Portugal	Farm level:	Farm level:	Farm level:	Farm level:	Farm level:
	MST 4,5,12:i:	*S.* Coeln	MST 4, [5],12:i:	*S.* Indiana	MST 4, [5],12:i:
	S. Cerro	*S.* Cubana	*S.* Cerro	ST	*S.* Agona

(*continued on next page*)

Table 5 (*continued*)

Country	2017	2018	2019	2020	2021
		S. Give	*S.* Anatum		*S.* Kapemba
	Abattoir/retail level:		ST	Abattoir/retail level:	*S.* Kedougou
	S. Coeln	Abattoir/retail level:		*Salmonella* (unspecified)	*S.* Newport
	S. Newport	MST 4, 5, 12:i:	Abattoir/retail level:		
	Salmonella (unspecified)	*Salmonella* (unspecified)	*Salmonella* (unspecified)		Abattoir/retail level:
	S. Kentucky				*Salmonella* (unspecified)
					MST 4,5,12:i:
Serbia	ND	ND	ND	Farm level:	Farm level:
				ND	ND
				Abattoir/retail level:	Abattoir/retail level:
				Salmonella (unspecified)	*Salmonella* (unspecified)
Sweden	Farm level (SVA, 2017):	Farm level (SVA, 2018):	Farm level (SVA, 2019):	Farm level (SVA, 2020):	Farm level (SVA, 2021):
	No positive flocks	No positive flocks	No positive flocks	No positive flocks	No positive flocks
	Abattoir/Cutting level (SVA, 2017):	Abattoir/Cutting level (SVA, 2018):	Abattoir/Cutting level (SVA, 2019):	Abattoir/Cutting level (SVA, 2020):	Abattoir/Cutting level (SVA, 2021):
	No positive samples	No positive samples	No positive samples	No positive samples	No positive samples

SE – *S.* Enteritidis, ST – *S.* Typhimurium, MST – monophasic variant of *S.* Typhimurium, SH–*S.* Hadar, SI–*S.* Infantis, SV–*S.* Virchow.
NA – not applicable; ND – no data.

[a] Turkeys fattened in Denmark are slaughtered abroad.

[b] No turkey fattening flocks in Estonia.

[c] At farm level only control programs for *S.* Enteritidis and *S.* Typhimurium in place for fattening turkeys. Serotyping of the top 5 only conducted for *Gallus gallus* flocks.

[d] Sampling regarding zoonosis monitoring (Dir. 2003/99/EC), but turkey was only included 2018, 2020 (pooled caecum, neck skin and fresh turkey meat).

past 40 years (accounting for 99% of slaughtered broilers and 91% of turkeys). Vaccination is not used in Sweden. In all these Nordic countries, thorough cleaning and disinfection procedures and thereafter environmental sampling, with *Salmonella*-negative results, are required before a holding can be restocked (Anonymous, 2022b; FMAF, 2021a; NMAF, 2004).

For the eastern European countries, sampling and operating instructions are specified by national law for Estonia (Regulation 105 (RT, 2024) and Poland (Anonymous, 2020c,d,e; 2022e,f). Vaccination is not used in Estonia. In Poland, no official vaccination program exists. However, many poultry companies vaccinate against *S.* Enteritidis and *S.* Typhimurium in poultry parent flocks.

For the western European countries, in France, the first control plan for *Salmonella* in poultry production was set up in 1998. *Salmonella* vaccination with inactivated vaccines for broiler and turkey breeders was prohibited until 2023 (Anonymous, 2023d); the ban remains for broiler and turkey flocks only. In the case of a *Salmonella*-positive breeding flock or broiler or turkey flock, the efficacy of the cleaning and disinfection operations is assessed with environmental sampling before a holding/house can be restocked. In Germany, additionally to official controls, a special QS scheme for *Gallus gallus* flocks and for the broiler and turkey fattening farms are laid down in guidelines for poultry holdings (Anonymous, 2023b) and for *Salmonella* monitoring and reduction for poultry production (Anonymous, 2023c). The sampling scheme consists of an entry and an exit control and is organised by the private organisation, QS. Vaccination of G*allus gallus* breeding flocks against *S.* Enteritis is mandatory and is allowed against *S.* Typhimurium if an infection is suspected (GeflSalmoV, 2009).

In the southern European countries Italy and Portugal, control programs are also set. In Italy, vaccination (both with attenuated and inactivated vaccines) is one of the main measures implemented to control target *Salmonella* serovars in poultry flocks. Vaccination is mandatory in *Gallus gallus* and turkey breeders when new flocks are introduced after the identification of a target serovar. In a flock vaccinated with an attenuated vaccine, when a target *Salmonella* strain is identified, the laboratory must discriminate between a field and a vaccinal strain. Moreover, in Italy, after the identification of a target serovar in broiler or turkey fattening flocks, before introducing a new flock, the efficacy of the cleaning and disinfection procedures implemented in the house where the positive flocks were hosted must be verified proving the absence of *Salmonella* spp. in at least five environmental samples (Italian Ministry of Health, 2022). In Portugal, *Salmonella* vaccination is optional. *Gallus gallus* breeding flocks that are positive for the target serovars Enteritidis or Typhimurium must be sent for slaughter, and after slaughtering positive flocks to any of the target serovars, the restocking flock is mandatorily vaccinated. Nevertheless, almost 99% of breeding flocks are vaccinated against *Salmonella*. Both inactivated and attenuated vaccines are approved and in use. Serotyping and differentiation between attenuated vaccine and field strains are performed exclusively by the national reference laboratory. In the case of positive flocks, after slaughter, the restocking of the poultry houses can only be done when negative environmental results are achieved (Portuguese Decree-law 164/2015).

In Serbia, measures for the early detection, diagnosis, prevention of spread, suppression, and eradication of specified *Salmonella* serovars in broilers, hens and turkeys are regulated by the national legislation (Republic of Serbia, 2018). By this program, the vaccination of broilers and pullets against *S.* Enteritidis and *S.* Typhimurium is allowed, while it is forbidden against *S.* Gallinarum and *S.* Pullorum. Vaccination of turkeys is not allowed.

The aim of reducing the prevalence at farm level is the same for all participating countries, but the requirements for positive flocks differ between them. On the one hand, *Salmonella*-positive flocks in some countries can be sent to abattoirs to be slaughtered at the end of the day (Estonia, Germany, France, Italy, Poland and Portugal) and the carcasses can be either tested for *Salmonella* or the meat thereof should be heat treated in a way which ensures *Salmonella* is killed (Estonia, Poland). On the other hand, a zero-tolerance for *Salmonella* exists (the Nordic countries), so *Salmonella*-positive flocks are culled on the farm and carcasses are sent to rendering plants. This practice is used in Finland too, even though legislation here allows the slaughter of positive flocks together with suitable heat-treatment of the meat afterwards (Finland, FMAF, 2021b). Most Finnish poultry farms have an insurance policy to cover the production losses of culled birds and eradication costs. In

Table 6
Salmonella in humans, source of notification, number of cases reported and five most detected serovars, 2020–2021.

Country	Notification mandatory	Legislation	Cases 2020 (Number of cases/100,000 population)	Main serotypes 2020	Cases 2021 (Number of cases/100,000 population)	Main serotypes 2021
Denmark	Yes	National monitoring programs and action plans	Anonymous, 2021: 614 cases (10.5/100,000)	Anonymous, 2021: SE ST including MST *S.* Dublin *S.* Strathcona *S.* Kottbus/*S.* Coeln	Anonymous, 2022c: 692 cases (11.8/100,000)	Anonymous, 2022c: ST including MST SE *S.* Braenderup *S.* Newport *S.* Dublin
Estonia	Yes	RT (2021)	Terviseamet, 2023: (6.9/100,000)	Terviseamet, 2023: SE ST MST 1,4 [5],12:i: *S.* Derby SI	Terviseamet, 2023: (8.6/100,000)	Terviseamet, 2023: SE MST 1,4 [5],12:i: ST *S.* Derby *S.* Newport
Finland[a]	Yes	Finnish Communicable Diseases Act 1227/2016	THL, 2021: (9/100,000)	THL, 2021: ST 48 Group B serotypes *S.* Saintpaul SE	THL, 2022: (9/100,000)	THL, 2022: ST SE Group B serotypes *S.* Poona
France	No, only for collective foodborne outbreaks	Anonymous (2020b)	9315 (28.7/100,000) Based on estimated population coverage of 48%	Institut Pasteur, 2022: SE MST 1,4 [5],12:i: ST *S.* Napoli SI	7.071 cases (21.9/100,000) Based on estimated population coverage of 48%	Institut Pasteur, 2022: SE MST 1,4 [5],12:i: ST SI S. Chester
Germany	Yes	IfSG (2022)	RKI, 2021: 8743 cases	RKI, 2021: SE ST incl. MST SI *S.* Muenchen *S.* Derby	RKI, 2022: 8122 cases	NP
Italy	Yes	DM 15 December 1990 DM, 7 March 2022; DM, 22 July 2022	2713 cases, (4.5/100,000)	MST 1,4 [5],12:i: ST SE *S.* Napoli *S.* Derby	3768 (6.4/100,000)	MST 1,4 [5],12:i: ST SE *S.* Napoli SI
Norway	Yes	NMHCS, 2003	39 cases (20,5/100,000) EFSA and ECDC	Jørgensen et al., 2021: SE ST *S.* Newport	390 cases (8,2/100,000) EFSA and ECDC	Jørgensen et al., 2022: SE ST *S.* Newport
Poland	Yes	Anonymous (2008)	EFSA & ECDC, 2022: 5192 (13.7 cases/100,000)	ECDC, 2023: SE ST SI *S.* Derby	EFSA & ECDC, 2022: 7702 (20.4 cases/100,000)	ECDC, 2023: SE ST SI *S.* Coeln
Portugal	Yes	Portuguese law nº 81/2009	ECDC (2023) 262 cases (2.54/100,000)	SE ST MST 1,4 [5],12:i:	ECDC (2023) 361 cases (3.98/100,000)	SE ST SI
Serbia	Yes	RS, 2017	SIPH, 2021: 631 cases (9.1/100,000)	SE ST *S.* Stanley	SIPH, 2023: 678 cases (9.83/100,000)	SE *S.* group B *S.* group C1
Sweden	Yes	Anonymous (2004)	SVA, 2020: 826 cases	SE ST MST 1,4 [5],12:i: *S.* Newport	SVA, 2021: 946 cases	SE MST 1,4 [5],12:i: ST

SE – *S.* Enteritidis, ST – *S.* Typhimurium, MST – monophasic variant of *S.* Typhimurium, SI–*S.* Infantis.
NP – data not published yet (status October 16, 2023).
[a] For Finland, only domestic cases are reported.

Denmark, *Salmonella*-positive broiler flocks are culled, and the producer gets compensation for the lost profit of the flock through their own Levy system established for this purpose. In Sweden, *Salmonella*-positive farms are blocked during the infection control investigation (Anonymous, 2014) and the cull that is required. The producers' costs for the loss of the production animals, cleaning and disinfection as well as production losses is covered by the insurance included in the voluntary control program. For smaller producers (less than 5000 poultry per year), 50% of the losses are compensated (in the mandatory program) or 70% (in the voluntary program) by the government (Anonymous, 1999c). The isolation of a target serovar in a broiler breeding flock in France entails the stamping out of the flock. The national insurance program 'Charte sanitaire' repays the losses if strict biosecurity measures are applied, which are checked by the veterinary authorities on a yearly basis.

3.2.3. Meat level (Tables 2–5)

National regulations specify the sampling at the abattoir or at retail level in Denmark (Danish Order No. 1819 of December 2, 2020), Finland (FMAF, 2021a), Italy (212/CSR, 2016), Norway (NMHCS & NMAF & NMTIF, 2008) and Serbia (Republic of Serbia, 2010b). In Germany, end products are tested regularly according to the retailer's requirements, which are not specified in any legislation.

In Finland, national legislation specifies that neck skin samples can be taken before chilling, contrary to EU legislation, if neck skin is removed before chilling. Sweden follows the EU regulation (EC, 2005c). Additionally, the Regulation (EC) No 1688/2005 (EC, 2005b) and Regulation (EC) No 853/2004 (EC, 2004b), Article 8 ensures Finland and Sweden special guarantees for imported poultry meat, or incoming from other EU-MS, that must have tested negative for *Salmonella* by approved methods. Denmark was also issued these guarantees for broilers in 2018 (EC, 2018). In Norway, the sampling frequency, set at once a week, can be reduced if there is a national or regional program to combat *Salmonella* and if the programs have shown low prevalence in animals sent to the abattoir. Additionally, national law allows that smaller abattoirs and establishments producing minced meat, processed meat and fresh poultry meat in small quantities, can be exempted from these sampling frequencies if justified based on a risk analysis and approved by the CA in (Norway NMHCS & NMAF & NMTIF, 2008). In Sweden, the annual sampling procedure at slaughter is decided by the Swedish Food Agency based on the slaughter volume at the establishment.

In Italy, national legislation refers to farm level and, in case broiler or fattening turkey flocks are positive for the target *Salmonella* serovars, the animals can either be killed on farm or slaughtered under CA supervision following specific sanitary measures that include a logistic slaughtering approach and carcass (neck skin) sampling according to Regulation (EU) No 1086/2011 (EC, 2011b). If the neck skin samples are positive for target serovars, the carcasses are destroyed or heat treated to eliminate *Salmonella* (Italian Ministry of Health, 2022).

3.3. Human level surveillance and control actions (Table 6)

Except for France, in all participating countries, the notification of salmonellosis in humans is mandatory. In France, the surveillance system is based on a voluntary network of medical practitioners and is estimated to cover 48% of the French population, so underestimation must be considered. Only collective foodborne outbreaks are notified to public health authorities on a mandatory basis, accounting for 40% if the foodborne infection outbreaks (Santé Publique France, 2021). The same under notification scenario applies in Portugal, which has one of the lowest salmonellosis case numbers in the EU, despite the compulsory notification of laboratory-diagnosed human cases (De Knegt et al., 2015).

The details of how to perform outbreak investigations are set down in national regulations, and the degree to which institutions are involved differ between the countries, but samples are mainly sent to reference laboratories to be serotyped or sequenced using cultural methods and/or PCR (this latter in Norway for example). The results must be reported to national health institutes and are mainly collected in databases, but the reports do not always specify the food implicated with the disease. In all countries, outbreak investigations are carried out.

Table 6 gives an overview of the number of cases and main *Salmonella* serovars found in 2020 and 2021 in humans in the participating countries.

4. Discussion

Salmonella control programs were mainly introduced to reduce the prevalence of this pathogen in poultry flocks in order to decrease the incidence of human salmonellosis. Hence, control programs are developed to target primarily those serovars (target serovars) that are most relevant to public health, namely *S*. Enteritidis, *S*. Typhimurium and the monophasic variant of *S*. Typhimurium. Moreover, additional criteria, such as antimicrobial resistance, virulence characteristics and the potential for rapid spread, are also identified to select additional serovars for inclusion in the control programs (EC, 2003b; Petrin et al., 2023).

Before the mandatory implementation of NCPs, the estimated EU prevalence of *Salmonella* in broiler flocks and fattening turkey flocks was 23.7% and 30.7%, respectively (EFSA, 2007; 2008a). By 2021, the prevalence has reduced to 3.8% in broiler flocks and 9.1% in fattening turkey flocks, and these data confirm the effectiveness of the overall EU approach of reducing the prevalence of *Salmonella* at farm level (EFSA & ECDC, 2022). These efforts have contributed to a significant reduction in human salmonellosis cases in the EU, from 153,852 reported cases in 2007 (EFSA & ECDC, 2013) to 60,050 in 2021. However, the previously observed decreasing trend seems to have stalled since 2014 (EFSA & ECDC, 2022).

When comparing the different countries included in the study, we observed that *Salmonella* NCPs are implemented for flocks of broiler breeding stock, broilers, turkey breeding flocks and fattening turkeys in all EU countries, as well as in the two non-EU countries, Norway and Serbia. In all countries, controls are performed at different production levels and are mostly based on the EU legislation. However, differences were identified, primarily when comparing regional areas. In the four Nordic countries (Denmark, Finland, Norway, and Sweden) and in Estonia, distinct control strategies have been implemented with very detailed requirements for feed control, farm surveillance and the handling of *Salmonella*-positive flocks. In fact, the Nordic countries started to control *Salmonella* in poultry by controlling this pathogen in feed in Sweden over 60 years ago, long before the implementation of mandatory NCPs in the remaining EU-MSs. In these countries, the poultry industry undertook voluntary initiatives for controlling *Salmonella* in the flocks. Hence, the Nordic countries have had a long history in controlling *Salmonella* in poultry flocks, and this has helped bring down the prevalence in poultry flocks; today, most human cases in these countries are associated with foreign travel. This also applies to Estonia, where a similar control program to that in Finland was established later, but has now been applied for decades, and it has reduced the prevalence of *Salmonella* in poultry flocks.

4.1. Feed level control

The introduction of *Salmonella* into the poultry flocks through contaminated feed is considered an important transmission pathway (Parker et al., 2022). This pathway also poses direct zoonotic risk, as studies have demonstrated a link between contaminated feed and the presence of *Salmonella* in broiler meat (EFSA, 2008b). Hence, the testing of feed and environmental samples for *Salmonella* and serotyping the isolates is a standard procedure in many countries. *Salmonella* is prevalent in the compound feed for poultry in the EU and it has recently ranged from a prevalence of 1.2% in 2016 to 0.29% in 2020. During this

period, among other serovars, *S*. Enteritidis, *S*. Typhimurium and *S*. Infantis were reported in feed by EU-MSs (EFSA & ECDC, 2017; 2018, 2019; 2021a,b). For the control of *Salmonella* in feed, the countries included in this study have taken different approaches in terms of sampling frequency. These approaches are either based on the amount of feed processed, production capacity, predetermined schedule, risk assessment or on the combinations of the aforementioned. Apart from the prohibition on using *Salmonella*-contaminated feed, which is implemented in all the countries, additional control measures are also taken, which range from the adequate thermal treatment of positive feed batches (Denmark, France, Italy, Norway and Serbia) to full suspension of feed production and distribution from *Salmonella*-positive plants (Finland and Sweden). Other measures implemented are tracing the source of contamination (Denmark, Estonia, Finland, Germany, Italy, Poland and Sweden) and enhancing the cleaning and disinfection procedures at feed mills (Denmark, Estonia, Finland, France, Germany, Italy and Sweden). As it is known that *Salmonella* can survive in the environment for a long time, CAs in many countries (Denmark, Finland, Germany, Norway and Sweden) also test environmental samples taken at feed mills and from storage locations. Environmental samples can be also taken within the framework of enterprise self-control activities. Parker et al. (2022) highlighted that assessing the extent of the contamination within the feed plant is paramount and should not only focus on raw feed material and finished feed, but also on environmental samples, namely dust and feed aggregates from different areas of the plant, providing a more sensitive approach for detection. In Finland, a single contaminated production line at a feed mill resulted in *S*. Tennessee findings in 50 pig and 40 laying hen holdings (EFSA, 2010). Moreover, there is evidence to show that some of the NCPs target serovars, namely *S*. Enteritidis, *S*. Infantis and *S*. Typhimurium, including its monophasic variants, are present in the environment of feed mills producing poultry feed (Gosling et al., 2022). Therefore, feed and feed mill environments are considered potential routes for introducing *Salmonella* serovars that are of public health importance into poultry flocks (Sargeant et al., 2021).

When heat treatment is routine for all commercial feed production, e.g., as part of the pelleting process, it is a true critical control point (CCP) against *Salmonella*. Sampling and testing will confirm the effect of this procedure. Without the CCP, sampling and testing will usually provide results too late to prevent distribution and spread of infection. Still, even after an effective treatment, feed recontamination can occur along the steps following heat treatment, namely during cooling and additional handling (EFSA, 2008b).

4.2. Farm level controls

Even though *Salmonella* can enter the food supply chain at any stage of production, its control at farm level is crucial, and is of paramount importance to reduce the levels of *Salmonella* at the processing stage. In primary production, many flocks can harbour *Salmonella* of differing serovars. In the EU, *S*. Typhimurium and its monophasic variants as target serovars were found in 3.6% and *S*. Enteritidis in 3.8% of the *Salmonella*-positive broiler flocks in 2021 (EFSA & ECDC, 2022). All NCPs at farm level aim for the prevalence of target serovars to be equal or below 1%, as mandated by the EU regulations (EC, 2010, 2012a,b). However, these target serovars differ among countries. While NCPs in Denmark, Finland, Norway and Sweden include all serovars for every type of chicken and turkey flocks, others, such as Germany, Italy, Poland, Portugal and, recently also Estonia only include the serovars stipulated by the EU legal requirements. The new Estonian Regulation (RT, 2024) has taken a shift from the previous approach, which was similar to the Finnish NCP, e.g. all serovars are included, focusing now on the EU target serovars. Besides the EU-regulated target serovars, the French NCP also includes *S*. Kentucky for all poultry flocks, and the Serbian NCP does not differ the target serovars between breeding hen, broiler and breeding and fattening turkey flocks.

EFSA's recent scientific opinion on *Salmonella* control in poultry flocks and its impact on public health (EFSA, 2019) justifies the retention of *S*. Enteritidis, *S*. Typhimurium including its monophasic variants and *S*. Infantis in the target serovars for breeding flocks. Moreover, it further highlights that since the most relevant serovars in breeding flocks differ and change with time between EU-MSs, *S*. Virchow and *S*. Hadar could be replaced by *S*. Kentucky and either *S*. Heidelberg, *S*. Thompson or another serovar according to the national prevalence targets (EFSA, 2019). We found that the five most frequently detected *Salmonella* serovars in broilers differed among the participating countries (Table 4), with the target serovars becoming less prevalent. However, for some countries like Italy, although the NCP was very effective in controlling the target serovars in broiler flocks, it appeared to be less effective in controlling *Salmonella* belonging to non-target serovars (EFSA & ECDC, 2022). In Italy, this scenario has been attributed mainly to a rise in the proportion of *S*. Infantis isolated from broiler chickens. Some studies suggest this surge to be a consequence of vaccination programs aimed at reducing *S*. Enteritidis and *S*. Typhimurium prevalence, which may have inadvertently created a conducive environment for the growth of *S*. Infantis. Moreover, *S*. Infantis possesses genetic adaptations favouring its persistence in the production environments (Montoro-Dasi et al., 2023).

Among countries, the sampling strategies and the types of samples collected differ. The common approach for sampling breeding broiler and turkey flocks involves collecting samples when they are day-old chicks and day-old poults, respectively, during their growing phase, and subsequently during their laying phase. In Finland and France, 4-week-old birds in breeding flocks also need to be sampled (Tables 2 and 3). In Finland, rather than using two pairs of boot socks to collect samples from laying breeding flocks, as in the other countries, only one pair is used, and the other one is substituted with an environmental sample. Typically, the flocks are sampled using two pairs of boot socks at one time point only, between 2 and 3 weeks before slaughter, except in Denmark, Germany and Serbia. Denmark employs a rigorous sampling scheme for broiler flocks, requiring sampling at two time points before slaughter and using five pairs of boot socks, contrasting with the remaining countries. In Germany, according to the QS scheme, a dust sample from the hatchery is also included as a control to monitor *Salmonella* infection in day-old chicks entering broiler houses. Additionally, for fattening turkey flocks, boot socks from the rearing farm are used for this purpose (Anonymous, 2023c). In Serbia, the sampling approach is notably different, and rather than using boot samples (although allowed and practiced to some extent), they collect pooled faeces samples, with the sample count adjusted based on the flock size.

While both FBOs and CAs, carry out sampling in all countries, the specific requirements set by the different NCPs differ. For instance, official sampling must be done either in a particular number of the flocks (1/3 of broiler flocks in Estonia), at a predetermined frequency (once per year in commercial broiler and turkey farms in Finland, France, Sweden and Norway) or on a minimum number of flocks depending on farm size (at least 1 flock per year in 10% of farms with more than 5000 broilers or more than 500 turkeys in Germany, Italy, Poland and Portugal).

Salmonella survives easily in outdoor environments (Newton et al., 2021), and therefore, it is of the utmost importance to apply efficient biosecurity measures to avoid on-farm contamination with this zoonotic pathogen. Thus, for example in Finland, France and Sweden, the official visit during CA sampling, besides official sampling, includes a detailed inspection aiming to improve biosecurity measures on the farm. Presently, no information on access to the outdoors is mandatory when reporting *Salmonella* prevalence in broiler and turkey flocks at EU level. This information is lacking for better understanding of *Salmonella* epidemiology in poultry, as access to an outdoor range remains a debated risk factor in scientific literature (EFSA, 2019).

One of the most striking differences between NCPs in the studied countries is the management of target serovar-positive flocks, which has a clear regional associated approach. In the Nordic countries studied, the

Salmonella-positive flocks are preferably culled on the farms, reducing the risk of contamination of transport vehicles and slaughter lines. The remaining countries slaughter *Salmonella*-positive flocks under logistic slaughter conditions. Additionally, Estonia requires that the meat resulting from *Salmonella*-positive flocks (all serovars) be heat treated to eliminate the pathogen. A similar measure is set in Poland, though the heat treatment of meat is only mandatory for *S.* Enteritidis- and *S.* Typhimurium-positive flocks.

4.3. Meat level controls

Another difference among countries can be found in the sampling plans and the location where sampling takes place at the meat level. While all countries implement control of the process hygiene and mainly the PHC for *Salmonella* as set by Regulation (EC) No 2073/2005 (EC, 2005c), in some countries, the number of tested neck skin samples varies mainly depending on the production volume. Here again regional specifics can be seen, as in the Nordic countries, with their focus on strict *Salmonella* control actions with zero-tolerance in meat and products thereof. Although slaughtering *Salmonella*-positive flocks is allowed, on the condition that meat is heat treated, Finnish poultry abattoirs usually do not accept *Salmonella*-positive flocks for slaughter. Thus, the normal procedure is to cull such flocks on farms, on a voluntary basis. To cover culling and eradication costs, most Finnish poultry farms have an insurance policy, as they also do in Sweden. This example shows that the Finnish and Swedish broiler and turkey industries are motivated and committed to strict *Salmonella* control measures to ensure *Salmonella*--free domestic poultry products on the market. A very different approach is undertaken in other countries, such as Italy and Portugal, since positive flocks are generally sent for slaughter rather than culled on farms. Strict logistic slaughter conditions are applied, and the FBO must adapt and put in place additional procedures to prevent carcass contamination, following the mandatory testing of positive flocks' carcasses following Regulation (EC) No 2073/2005 (EC, 2005c) or heat treatment of meat thereof. Therefore, the associated economic burden is not carried exclusively by the broiler and turkey farmers, and there is more pressure than usual on FBOs to control *Salmonella* throughout the slaughter process.

In the countries where on-farm restrictive control measures are specifically implemented for broiler and turkey flocks positive for target serovars, no specific control measures are applied to animals arriving at slaughter positive for the other *Salmonella* serovars. Among these, *S.* Infantis is of concern, being widespread in broilers (Mughini-Gras et al., 2021; Perilli et al., 2022; Shah et al., 2017; Vinueza-Burgos et al., 2019) and turkeys (EFSA & ECDC, 2022). In Europe, during 2021, poultry meat remained one of the main vehicles for *Salmonella* dissemination, as shown by the number of *Salmonella*-positive samples in the context of PHC controls referring to the target serovars (EFSA & ECDC, 2022). Interesting, the top three serovars associated with broiler meat in the EU in 2021 were *S.* Infantis (45.1%), *S.* Enteritidis (8.0%) and *S.* Livingstone (7.0%) (EFSA & ECDC, 2022), confirming that non-target serovars might be found in meat placed on the market. These data strongly support the need for a periodic reassessment of the serovars to be controlled in the poultry chain in the EU.

4.4. Human level control

Overall, it can be said that setting reduction targets for *Salmonella* in laying hens, broilers and turkeys within NCPs in the EU has been effective in reducing human salmonellosis cases in the EU during the initial ages of their application (Poirier et al., 2008). At this time, we saw an initial reduction of human cases that was related to the set targets and the introduction of the control programs in poultry (Tzani et al., 2021). However, the trend for confirmed cases of salmonellosis in humans in the EU has stabilised since 2014, and in the most recent years, the overall trend of human salmonellosis in the EU did not show any statistically significant increase or decrease (EFSA & ECDC, 2022). In 2020, the number of human cases of salmonellosis was the lowest since the beginning of EU *Salmonella* surveillance in 2007, and the following year, a slight increase was reported, although the number did not reach that of previous years. This drop of human cases of salmonellosis cannot be attributed to a real change of the EU epidemiological situation, but it was related to the COVID-19 pandemic and to the effect of the implemented restrictive measures (e.g. the limitation of social events, travel, and doctor's visits) (EFSA & ECDC, 2022).

The notification rate of human salmonellosis varied notably over time and among the countries involved in the study and, according to the data reported in the EU One Health Zoonoses Report over the period 2017–2021, it ranged from 2.9 of Portugal in 2018 to 28.7 of France in 2021 (EFSA & ECDC, 2022). This high variation can be due to the real status in each country of the *Salmonella* circulating among the different sources, but it can also be a direct consequence of the quality and coverage of the monitoring and surveillance systems in place in the different EU-MSs (EFSA & ECDC, 2022). In particular, the notification of human salmonellosis is not mandatory in all countries investigated and countries differ in their identification of positive cases and outbreak investigations.

In relation to serovar distribution, looking at the EU situation, *S.* Enteritidis is by far the most frequent serovar associated with human cases of salmonellosis (64.6%), followed by *S.* Typhimurium (11.0%) and monophasic variants of *S.* Typhimurium (3.5%). Overall, these three target serovars accounted for almost 80% of the human cases acquired in EU-MSs in 2021 (EFSA & ECDC, 2022), and this explains their large public health impact. The epidemiological situation justifies their identification as target serovars in primary production for poultry flocks. A different scenario is seen for *S.* Infantis, *S.* Virchow and *S.* Hadar, which, although are listed as target serovars for breeding hens (EC, 2010), are occasionally isolated from humans (EFSA, 2019) and according to data published in the European Surveillance System TESSy (https://atlas.ecdc.europa.eu/public/index.aspx?Dataset=27&HealthTopic=46), they accounted for 1.7%, 0.53% and 0.28%, respectively, of the confirmed human cases reported in the EU in 2022.

In order to infer the relevance of the poultry meat production chain as a cause of human salmonellosis, comparing the *Salmonella* serovar distribution in humans, as confirmed by the data reported by TESSy, with those in broiler and turkeys is a first step. The situation in the different countries is very diverse. In Poland, *S.* Enteritidis is by far the most commonly isolated serovar from humans, and it is also the top serovar from broilers and turkeys; in this situation, it is clear how the control measures addressing poultry production are crucial to obtain a reduction of *Salmonella* in humans. A similar situation was seen in Denmark, where monophasic variant of *S.* Typhimurium has been reported as the most common serovar from broiler since 2020, and it also appears at the very top level from the human cases. Conversely for Italy, *S.* Typhimurium and monophasic variant of *S.* Typhimurium are the serovars most commonly associated with human infections, but they do not compare within the list of the top five serovars for broilers and turkeys, which instead holds non-target *Salmonella* serovars (Tables 4 and 5). These findings suggest how in this specific epidemiological situation, *Salmonella* control programs should be extended to sources other than poultry to lead to a reduction of human cases of salmonellosis.

Moreover, this comparison among serovars circulating in humans and those from broilers and turkeys clarifies how there are serovars, like *S.* Infantis, which is described as an emergent serovar because of its constantly increasing prevalence in poultry especially in some countries (i.e. Italy, Poland and Germany), but which sometimes appear within the top five serovars responsible for human cases (Tables 4–6).

4.5. Future perspective

The control actions for *Salmonella* in poultry should be regularly reviewed and, if necessary, adapted in a way that food safety and

consumer protection are continuously strengthened. Future risk-based meat safety assurance systems (RB-MSAS) should, therefore, increasingly rely on a combination of successful mitigation strategies. In the Nordic countries, for example, there are nowadays only a few *Salmonella*-positive poultry flocks detected annually. So, it could be helpful in countries with a high incidence of disease in humans to look at the implemented *Salmonella* control measures in these countries and in those with low *Salmonella* prevalence and consider transferring the measures into their own NCPs. This could be a combination of detailed procedures as in Denmark, Sweden and Finland and starting at farm level, and in addition to process hygiene control and the implementation of zero tolerance in meat.

It needs also to be considered that the target serovars should be not only the five serovars fixed in former times in the EU regulations (EC, 2010, 2012a, b), but should also include frequently found serovars at regional or country levels. Such a flexible approach is dependent on well-designed surveillance, standardised methods and transparency of results. This approach will always be reactive, not proactive. One possible adaption in the framework of RB-MSAS could be to have the EU target serovars and to also include the most prevalent serovars detected in broiler and turkey flocks when they cause a relevant public health impact, and those most commonly involved in terms of foodborne outbreaks in humans over recent years. That was the case for *S.* Kentucky, which was added to the target serovar list in France in 2015. This decision was triggered by the first outbreak of ciprofloxacin-resistant *S.* Kentucky ST-198 in a turkey flock and was to prevent the dissemination of this specific serovar in the poultry sector (Guillon et al., 2013). No outbreaks of ciprofloxacin-resistant *S.* Kentucky ST-198 occurred in poultry flocks in France since. Choosing national specific target serovars, additionally to those defined at EU level, could be an effective strategy (Leati et al., 2021) to further reduce human salmonellosis. However, this strategy should be assessed in terms of cost-benefit ratio as well as implications for EU trade to estimate its real impact and the quantify the benefit reachable at community level. One of the major drawbacks of the current EU strategy to control *Salmonella* in poultry populations according to Regulation (EC) No 2160/2003 (EC, 2003b) is its strict relation to the 'serovar', as this strategy does not properly consider the real pathogenicity potential displayed by a *Salmonella* strain, which is generally related to specific genetic features, often unrelated to the serovar (Cheng et al., 2019; Marcus et al., 2000; Silva et al., 2017). According to the current EU legislation for *Salmonella* control on poultry farms, the isolation of a strain belonging to a target serovar, irrespective of its virulence, leads to severe measures, such as the immediate flocks' culling or slaughter and the application of sanitation measures (e.g. heat treatment of carcasses), with important consequences on the economy of the meat and egg chains. This strategy does not take into consideration the possibility of highly pathogenic *Salmonella* strains, not belonging to target serovars, but which could have pathogenicity features, with potential public health implications (Petrin et al., 2023). Such strains could spread as emerging clones, becoming potential causes of new outbreaks. So far, the identification of virulence patterns to unambiguously predict *Salmonella* pathogenicity in different hosts remains very challenging, and currently this is not included in the control programs.

5. Conclusions

The current study revealed that there are many differences in the investigated countries regarding *Salmonella* control and epidemiological situation. Some countries have NCPs that are in accordance with EU legislation but are also specified in national regulations or guidelines with very detailed requirements in feed control, farm surveillance and the subsequent handling of *Salmonella*-positive flocks. This kind of risk management has resulted in a very low prevalence of *Salmonella* in poultry meat. In each country, the target serovars should include the most prevalent serovars in that country's broiler and turkey meat chains. Moreover, changes in serovar prevalences over time should be easily checked through the mandatory implementation of PHC at slaughter and FSC for fresh meat. Future RB-MSAS will need to rely on suitable a combination of successful reduction strategies, including the harmonisation of sampling strategies and schemes.

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Declaration of competing interest

All authors declare no conflict of interest.

Data availability

All data presented is publicly available.

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