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SUMMARY

The French surveillance system for *Salmonella* is based on a national system which can be traced back to 1947 for human cases and to the late 1980s for the main animal reservoirs. This system has evolved with regard to both European regulations and changes in the observed prevalence of *Salmonella*. European regulations establish a solid foundation on which to build an active harmonised surveillance system at the production level and for integrating data from the whole food chain. There are also passive surveillance networks in the agri-food and veterinary sectors and these allow complementary information to be obtained from other sectors or sources. The main strengths and weaknesses of these systems are described and a comparison of the different approaches is presented using a grid analysis. The results show that passive systems are very useful for detecting emerging or unusual events and for early warning of outbreaks. They also produce time series of cases or can determine the number of strains that should be used to assess the impact of interventions. Active surveillance data, due to their representativeness and reliability, are key elements in the application of risk analysis tools such as quantitative risk assessment or attribution. Thus, although data is collected and analysed by various organisations, these organisations all collaborate at a national level. Furthermore, their implication in European and international projects is effective and the main objectives of a surveillance system can be met.

Keywords: Food safety, *Salmonella*, Integrated surveillance, Zoonosis, Antimicrobial resistance, Epidemiology.

RÉSUMÉ

Structure du dispositif français pour la surveillance de *Salmonella* isolée de la chaîne agro-alimentaire

Le système de surveillance français actuel est basé sur un système national préalablement existant, remontant à 1947 pour les cas humains et à la fin des années 80 pour les réservoirs animaux principaux. Ce système a évolué sous l'effet combiné de la réglementation européenne et des niveaux de prévalence des salmonelles observées dans les différentes sources. La réglementation européenne constitue un support majeur pour la construction d'un système de surveillance institutionnel harmonisé au niveau élevage et facilite l'intégration des données recueillies tout au long de la chaîne agro-alimentaire. L'existence concomitante de réseaux de surveillance passifs dans les domaines agro-alimentaires et vétérinaires permet d'obtenir des informations complémentaires sur des secteurs ou points de recueil de données non couverts par la surveillance institutionnelle. Les forces et les faiblesses de ce système sont décrites et les différentes approches sont comparées au travers d'une grille d'analyse harmonisée. Les réseaux de surveillance passive (événementielle) apparaissent très utiles pour la détection d'événements émergents ou inhabituels et pour les alertes précoces de foyers épidémiques. Ils produisent des séries temporelles de cas ou de nombres de souches permettant d'évaluer l'impact des interventions. La qualité et la représentativité des données de surveillance active en font des éléments clés pour appliquer des outils d'analyse de risque comme l'analyse quantitative de risque ou l'attribution. Ainsi, malgré la dispersion des données entre différents acteurs, le système se révèle efficace et apte à remplir ses objectifs grâce aux collaborations mises en place au niveau national et à l'implication commune des différents acteurs dans des projets européens et internationaux.

Mots clés : Sécurité alimentaire, *Salmonella*, surveillance intégrée, zoonose, Antibiorésistance, épidémiologie.

Introduction

In a context of industrialisation and globalisation of the food supply, where risk behaviours among consumers (eating raw or undercooked food, poor kitchen hygiene) are frequent and susceptible populations such as the elderly and immune-deficient patients steadily increase, foodborne diseases are a priority issue and remain a critical problem despite all the efforts made to prevent them (1).

Cases of human salmonellosis reported in Europe have decreased over the past three years, but *Salmonella* is still one of the most frequently reported causes of foodborne zoonoses (2). For the 1995-1999 period, the French Institute for Public Health (InVS) has estimated that the total annual number of confirmed cases in France was between 30,600 and 41,140, of which 92 to 535 led to the death of the patient (3).

Moreover, antimicrobial resistance (AMR) in *Salmonella* has been described for antimicrobials used for treating acute gastroenteritis in humans (third-generation cephalosporins, fluoroquinolones) and AMR has been defined as a risk factor increasing morbidity and mortality in humans (4). It is thus of utmost importance to control the transmission of *Salmonella*,

and especially that of resistant strains of *Salmonella*, from animals to humans.

To determine optimal management measures to control this zoonosis, it is necessary to assess the risk of consumer exposure to *Salmonella* contamination in food as it passes through the whole food chain. This requires information on prevalence, serotypes, AMR, food consumption, etc. In this context, surveillance systems for *Salmonella* have been implemented in the public health and the agri-food sectors. Such systems must include trained personnel, diagnostic laboratory support, data collection and analysis capabilities (5). To gain a global overview of the systems involved for *Salmonella* surveillance in France and to analyse their specificity and complementarity, an analysis grid was defined based on OIE (terrestrial animal health code, chapter 6.5) and the European Food Safety Authority (EFSA) guidelines (6); it was applied following the evaluation steps described in CDC guidelines (7). Major criteria describing the objectives, the operational system and the nature of collected data were included in this analysis for current surveillance systems. Systems which don't work anymore are not included.

This paper thus presents the structure, limitations and developments of the French surveillance system regarding *Salmonella* within the framework of the European "farm-to-table" monitoring approach, focusing on the main reservoirs: food animals and related products.

Structure of the *Salmonella* surveillance system

Salmonella, as a zoonotic pathogen, is the subject of several European regulations. This section presents the European regulatory framework and the structure of the national surveillance system, from human cases to animal sources. The organisations involved in this system have previously been described (8) (Figure 1).

PUBLIC HEALTH SECTOR

European regulatory framework

Surveillance of communicable diseases is based on networked expertise in the EU Member States as endorsed by Commission Decision 2119/98/EC. In 2005, under the Zoonosis Directive (Directive 2003/99/EC), salmonellosis and agent thereof have to be included in monitoring (9). At the same time, the European Centre for Disease Prevention and Control (ECDC) was established (Regulation (EC) no. 851/2004) to enhance the capacity of the European Community and its Member States to protect human health through the prevention and control of human diseases. As far as reporting is concerned, the EFSA and the ECDC jointly analyse all data from the public health and agri-food sectors. The results are published in an annual Community Summary Report (2).

National surveillance system (Table 1)

The declaration of foodborne outbreaks has been mandatory in France since 1952 (Decree no. 52-953 of 7 August 1952), instigating surveillance of outbreak cases. Foodborne outbreaks are defined as the occurrence of at least two cases with common, most often gastro-intestinal, symptoms that can be linked to a common food source. The InVS defines a foodborne outbreak as caused by a confirmed agent when the agent is isolated either in human samples (blood, feces) or in food

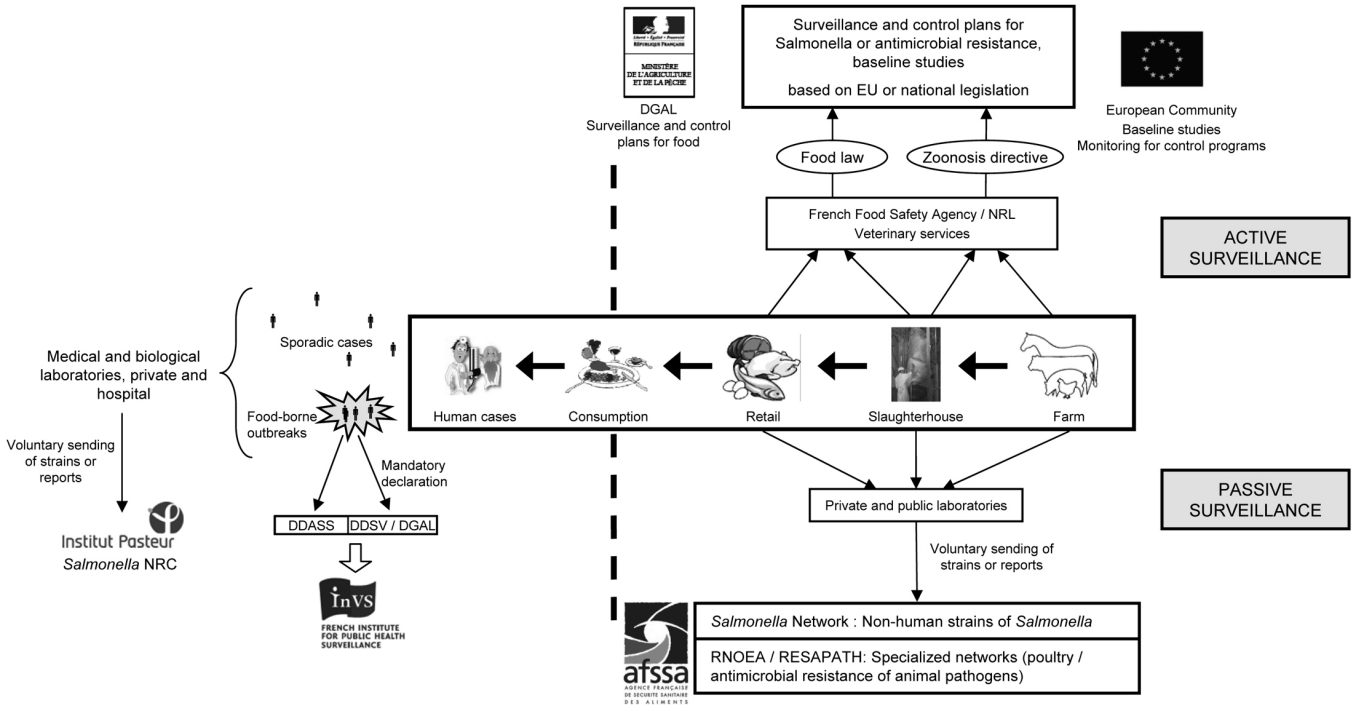

FIGURE 1: Organisation of the *Salmonella* surveillance system in France in 2008.

	National public health network: foodborne outbreaks	**National Reference Centre for *Salmonella***
Coordinator	InVS	NRC
Objectives	Establishment of records on foodborne outbreak events, including the biological agent, the food item involved and the number of cases	Temporal trends in serotypes and AMR of human cases Alerts in case of unusual events (number of cases)
Means of data collection	Passive surveillance	Passive surveillance
Scope of surveillance	National	National
Monitoring period	Continuous since 1987	Continuous since 1947
Pivotal variable[a]	Number of outbreaks, number of cases per outbreak	Number of cases per serotype
Disease focus	General - multi-pathogens	*Salmonella* specific
Design	Descriptive + risk factors	Descriptive
Temporality	Trends	Trends
Availability of non pivotal information	Yes	Yes
Way of selection	Non-random	Non-random
Source of data	Mandatory disease notification	Laboratory investigation records and biological specimen banks based on opportunistic collection
Coverage of the population	OK (mandatory)	2006: 1357 laboratories, including 1028 private laboratories and 329 hospital laboratories, 30 to 40% of French clinical laboratories
Duplicates	Eliminated	Eliminated
Target population	Foodborne outbreaks occurring in France	*Salmonella*-infected people
Study population	Foodborne outbreaks occurring in France that are notified	Cases confirmed by a laboratory collaborating with the NRC
Epidemiological unit	Outbreak	Strain
Case definition	Illness in at least two people with similar most often gastro-intestinal symptoms that can be attributed to the same food source	*Salmonella* strain identified in the sample
Laboratory testing	Not mandatory. For *Salmonella* confirmed outbreaks: private or hospital laboratory for identification of human cases of salmonellosis, NRC for serotyping. For veterinary isolates: LVD for identification and ANSES for serotyping	Identification / Serotyping / Resistance phenotype (Disk Diffusion method, E-test) / Genotype (PCR, PFGE, MLVA, BLSE)
Data collection and management	DT, DDPP, InVS	NRC
Analytical methodologies	Descriptive. Case-control studies or cohort studies can be conducted using data not given in the mandatory notification of foodborne outbreak	Descriptive Specific for unusual event detection
Quality assurance	For missing or invalid data, further enquiries addressed to the DT or the DDPP	Enternet quality control "Quality approach" as implemented at the Pasteur Institute
Sources of bias	Importance of the clinical symptoms Availability of samples to identify the biological agent Diffuse outbreaks Family outbreaks are less reported than collective or commercial catering outbreaks	Importance of the clinical symptoms Willingness of the laboratories to participate Population groups at risk
Reporting	Report: Weekly epidemiological bulletin, scientific publications	Annual report, scientific publications

[a]: *variable describing the quantity corresponding to the main objective of the survey.*

TABLE I: Surveillance of human cases in 2008.

leftovers or in control samples of the incriminated meal. Outbreaks must be notified to either the official departemental (*départements* are subdivisions of the national territory) public health or veterinary services (named DT of the Health Regional Agency and DDPP, respectively). The InVS centralises these data on a national level. The DDPP and DT databases are merged and duplicate data are discarded. In 2007, data on 1,436 foodborne outbreak cases associated with *Salmonella* were reported by the InVS. For some outbreaks, specific epidemiological investigations are performed, using data collected through further enquiries data provided by the National Reference Center (NRC) and data on food from the *Salmonella* Network (described below in § 1.2.2.2) (10-12). Descriptive results and epidemiological studies are published in the weekly epidemiological bulletin (Bulletin épidémiologique hebdomadaire, http://www.invs.sante.fr/BEH/) and in scientific publications (13-15).

No mandatory notification is required for sporadic salmonellosis cases. However, through a passive, laboratory-based surveillance of *Salmonella* in human samples, carried out by the NRC since 1947, data on sporadic cases are collected. This surveillance system relies on a stable network of voluntary clinical laboratories (private or hospital-based) representing 30 to 40% of all French clinical laboratories involved in human medicine in 2008. Laboratories send either strains of *Salmonella* to the NRC or send reports on the strains isolated

and serotyped. Strains and reports are filed along with epidemiological information such as travel history, age and sex of the patient, type of sample taken (stool, blood, etc.) or geographic location. A biological specimen bank and a national database of human strains have been set up. The NRC files data on about around 10,000 cases a year. Statistical analyses are performed on a weekly basis to detect unusual events and dispersed outbreaks, and all surveillance data are communicated to the InVS that investigates the unusual events. Data and analyses are published in the annual activity report of the NRC (http://www.pasteur.fr/sante/clre/cadrecnr/salmcnr/salmcnr-actualites.html) and through scientific publications (16).

AGRI-FOOD SECTOR

European regulatory framework

Salmonella in food animals

The first step in *Salmonella* surveillance in food animals at the European level was the implementation of Council Directive 1992/117/EC. This Directive involved measures for protection against specified zoonoses and zoonotic agents, in animals and products of animal origin, in order to prevent outbreaks of foodborne infections. One goal of Directive 1992/117/EC involved controlling *Salmonella* in the chickens (*Gallus gallus*), i.e. broilers and laying hens, focusing especially on the eradication of the serotypes Enteritidis and Typhimurium in breeding animals.

In 2003, this Directive was replaced by Directive 2003/99/EC of the Council and Parliament and Regulation (EC) no. 2160/2003. Directive 2003/99/EC on the monitoring of zoonoses and zoonotic agents aims to improve and coordinate the monitoring of zoonotic agents in the Community and to collect data that is easier to compile and compare. This should facilitate hazard identification and characterisation, as well as the assessment of exposure to zoonotic agents. *Salmonella* and its AMR are covered by this harmonised monitoring. Regulation (EC) no. 2160/2003 describes the progressive and proportional implementation of control measures regarding *Salmonella* and other specified foodborne zoonotic agents at the European level. Member States must set up programmes to reduce the prevalence of *Salmonella* in farm animals and products of animal origin. Poultry (broilers, laying hens and turkeys) and pigs, considered as the major animal reservoirs, are the primary livestock species targeted by these control measures at the breeding and production level. Within this framework, harmonised prevalence studies, so-called "baseline studies", have been conducted since 2004 to obtain scientifically relevant data on the initial level of prevalence in each Member State. On the basis of these results, reduction targets are set species by species for specified serotypes. For example, a maximal prevalence of 1% had to be met for the serotypes Hadar, Infantis, Virchow, Enteritidis and Typhimurium by the end of 2009 in breeding flocks of chickens (Regulation (EC) no. 1003/2005).

Salmonella in food

In 2002 the European Parliament adopted the "Food Law", (Regulation (EC) no. 178/2002), laying down the general framework to ensure a coherent approach in the development of food legislation from farm to table; the EFSA was created as part of this regulation. The "Food Law" establishes principles and responsibilities, the means for providing a strong scientific base and efficient structures and procedures to underpin decision-making in matters of food and feed safety. The principle of transparency for the consumer is also established. A package of three regulations and one directive constitutes the food hygiene legislation dedicated to food business operators (FBOs) and is supplemented by two other regulations relating to official controls and feed hygiene.

General rules for FBOs, including primary production, are laid down by Regulation (EC) no. 852/2004. FBOs must ensure that their products satisfy the hygiene requirements set by Regulation (EC) no. 2073/2005 specifying the microbiological criteria and the implementation of hygiene rules. Set criteria include the absence of *Salmonella* in the food product in terms of safety criteria (i.e. defining the acceptability of the product) as well as at specific stages of the food processing procedure in terms of process hygiene criteria (i.e. setting an indicative contamination value above which corrective actions are required). These criteria are to be met according to HACCP (Hazard Analysis Critical Control Points) principles and must be scientifically justified. To ensure compliance with the "Food Law", official controls are performed according to Regulation (EC) no. 882/2004. They must be planned on the basis of risk assessment, relying on a scientific approach, in order to make an objective selection of products and operators to be controlled.

Antimicrobial resistance in food animals

Since the end of the 1990s, several international scientific reports and recommendations have led to publications recommending the harmonisation of surveillance and the regulation of foodborne AMR and the use of antimicrobials in animals, based on public health issues (WHO, 1997 and 1998; Copenhagen, 1998; FAO/WHO/OIE 2003 and 2007, Codex 2005, OIE 2006). Consequently, a European strategy to fight AMR has been defined in agreement with the "precautionary principle". The use of antimicrobials as growth promoters in food animal production has been banned (Council Regulations (EC) no. 2821/98 and (EC) no. 2788/98). At the same time, surveillance for non-human use of antimicrobials has been implemented at farm level. Although antimicrobials are used in the primary production, the surveillance of antimicrobial resistance in food-borne pathogens is performed at the level of primary production and other stages of the food chain, such as in food, as recommended by the Directive 2003/99/EC. A European Union Reference Laboratorie (EU-RL) has been designated and funded to promote harmonisation of the methods used to assess AMR. For *Salmonella*, a harmonised, continuous monitoring system in food animals is being implemented on the basis of a selection of strains isolated during the mandatory control programmes (Decision 2007/407/EC). National data on AMR have been reported to and published by the EFSA since 2003 (2).

National surveillance system

The national surveillance system for *Salmonella* in the agri-food sector relies on active institutional surveillance coordinated

by the French Directorate for Food (DGAL) operating under the European regulatory framework, supplemented by a passive system based on networks centralising non-human strains of *Salmonella* from public and private veterinary laboratories. Both surveillance systems are presented in the following sections.

Active surveillance system

Salmonella in feed

Feed suppliers for chicken and turkey breeders must comply with specific conditions covered by the "Agrément *Salmonella*". Batches are tested for *Salmonella* and the process must ensure a 3 log reduction of *Enterobacteriaceae*, used as indicators of *Salmonella* presence.

Salmonella in food animals (Table 2)

Based on a pre-existing voluntary program, the continuous mandatory monitoring and control programme in chicken breeding flocks has been implemented in France since 1998 in accordance with Directive 1992/117/EC. The serotypes Enteritidis and Typhimurium were targeted in breeding flocks of broilers and laying hens until 2007. Since 2007, this programme has been modified in line with Regulation (EC) 2160/2003, implementing updated regulations concerning the

	European control programmes	**European baseline studies**
Coordinator	DGAL	DGAL
Objectives	Control of Salmonella prevalence in poultry	Evaluation of the prevalence level of Salmonella at the farm level or at the slaughterhouse level
Means of data collection	Active surveillance	Active surveillance
Scope of surveillance	National	National
Monitoring period	Continuous since 2007 (1998 for Enteritidis (SE) and Typhimurium (ST) in breeding flocks)	12 months, from 2004 to 2009 according to the sector (Laying hens, pigs, broilers…)
Pivotal variable	Prevalence: SE, ST, Hadar, Infantis, Virchow for breeding flocks (laying hens and broilers) and SE, ST for production flocks of laying hens and broilers	Prevalence per serotype
Disease focus	*Salmonella* specific	*Salmonella* specific
Design	Descriptive + risk factors	Descriptive + risk factors
Temporality	Trends	Cross sectional
Availability of non pivotal information	Yes	Yes
Way of selection	Structured	Structured
Methods of selection	Exhaustive	Random selection Stratification on the farm or slaughterhouse size
Representativeness	Not relevant	OK
Target population	Breeding flocks (from 2007 on), laying hens (from 2008 on), broilers (from 2009 on)	Production and breeding flocks of laying hens, broilers, pigs and turkeys Flocks or animals either at the farm level and/or at the slaughterhouse
Study population	Registered farms Breeding flocks: over 250 animals Production flocks of laying hens: over 250 animals delivered to a conditioning unit Production flocks of broilers: all the flocks except under 250 directly delivering to the consumer	Laying hens, broilers, pigs and turkeys farms or slaughterhouses Registered farms of a minimal size Slaughterhouses of a minimal size
Epidemiological unit	Building	Flock, herd, holding or animals according to the sector
Case definition	At least 1 positive sample for broilers, at least 2 consecutive positive samples for breeders and laying hens	At least 1 positive sample
Laboratory testing	Laboratories with accreditation isolation / identification / serotyping (NFU 47100)	NRL for *Salmonella* Isolation / identification / serotyping
Data collection and management	DGAL / Departmental Veterinary Authorities	DGAL / NRL
Analytical methodologies	Descriptive (investigation if contamination)	EFSA, Specific / NRL at national level
Quality assurance	Certified laboratories	NRL / certified laboratories
Validation (bias)	Small flocks not included Direct sale of broilers not included Multicentric (investigator bias)	Small flocks and slaughterhouses not included Detection (a few units per building or batch at the slaughterhouse)
Reporting	Annual Community report Internal communication	EFSA reports / NRL scientific publications

TABLE II: Active surveillance of food production animals in 2008.

control of *Salmonella*. To date, the control of *Salmonella* includes the serotypes Enteritidis, Typhimurium, Hadar, Infantis and Virchow for breeders, and only Enteritidis and Typhimurium for chicken in production farms. This surveillance programme has been extended to fattening and breeding turkeys, and it still targets the serotypes Enteritidis and Typhimurium. For the purpose of French regulations, the surveillance includes also Typhimurium-like strains (i.e. serotypes 1,4,[5],12 :i :- or 1,4,[5],12 :- :1,2 or 1,4,[5],12 :-:). Regulated serotypes are defined as notifiable diseases subject to public health policy measures (Rural Code, article D223-21) and as such, are mandatory declared. However, all *Salmonella* serotypes are classified as notifiable diseases not subject to public health policy measures (Rural Code, article D223-1) for the regulated livestock sectors, so that information is available on all the serotypes. The continuous monitoring programme concerns specified flocks (Table 2) and is thus exhaustive for all regulated livestock sectors (i.e. breeding flocks and production flocks of chicken and turkey). This is to lead to an annual database giving information on the national prevalence of the different *Salmonella* serotypes and their trends in the regulated livestock species at the farm level.

To prepare the enforcement of these monitoring and control programmes, the initial level of prevalence of *Salmonella spp*. has been evaluated through baseline studies between 2004 and 2009. Sampling plans were designed to assess a prevalence of 20 to 50% (according to the animal species) with a precision of 3 to 5%. They are overseen by DGAL and by national and departmental veterinary services in collaboration with the National Reference Laboratory (NRL) for *Salmonella*.

Salmonella in food (Table 3)

In accordance with the “Food Law”, the DGAL implements national programmes either to assess consumer exposure ("surveillance plans" providing scientific evidence) or to detect anomalies or non-conformities by FBOs ("control plans"). In the first case, randomised sampling is performed; in the second case, sampling targets one type of food operator or one food

	Surveillance plans	**Control plans**
Coordinator	DGAL	DGAL
Objectives	Evaluation of the prevalence level of *Salmonella* in carcasses and products Specific questions such as comparison of sampling methods	Evaluation of the prevalence level of *Salmonella* on carcasses and products
Means of data collection	Active surveillance	Active surveillance
Scope of surveillance	National	National
Monitoring period	Several months to one year	Several months to one year for broiler meat
Pivotal variable	Prevalence (spp. or per serotype)	Prevalence per serotype
Disease focus	*Salmonella* specific	*Salmonella* specific
Design	Descriptive	Descriptive
Temporality	Single occurrence	Single occurrence
Availability of non pivotal information	No	No
Way of selection	Structured	Structured
Methods of selection	Random selection of slaughterhouses stratified by size Random selection of units	Random selection of slaughterhouses or producers or targeted selection according to specific activities
Representativeness	OK	OK
Target population	Carcasses from the targeted animal species Products in approved business units	Carcasses from the targeted channels Meat products: poultry, minced and mechanically separated meat
Study population	Food animals slaughtered in the selected slaughterhouses, products or retail units available in the targeted businesses (producers or retail business)	Pigs, large cattle and sheep slaughtered in the selected slaughterhouses Products in the selected factories
Epidemiological unit	Carcass, retail unit	Carcass, batch
Case definition	At least 1 positive sample	At least 1 positive sample
Laboratory testing	Laboratories with accreditation or LDA and ANSES isolation / identification / serotyping (ISO 6579)	LVD isolation / identification / serotyping
Data collection and management	DGAL	DGAL
Analytical methodologies	Descriptive and specific	Descriptive
Quality assurance	COFRAC accreditation for meat products ISO 6579	COFRAC accreditation for meat products ISO 6579
Validation (bias)	Large flocks have a higher probability of being sampled Multicentric (investigator bias)	Large flocks have a higher probability of being sampled Multicentric (investigator bias)
Reporting	Memos, internal communication Report (synthesis) on the French Ministry of Agriculture website	Memos, internal communication Report (synthesis) on the French Ministry of Agriculture website

TABLE III: Active surveillance of food in 2008.

category, including imported products. If necessary, as the French NRL for *Salmonella*, the French Agency for Food Environmental and Occupational Health and Safety (ANSES) (formerly AFSSA) is consulted for defining protocols. In accordance with Regulation (EC) no. 882/2004, control and surveillance plans performed by veterinary services are implemented on a yearly basis. The collected data give information on the prevalence of *Salmonella* in various food products, at the slaughterhouse and/or at the retail level.

Antimicrobial resistance monitoring

Since 1999, the Directorate for Food has sponsored monitoring plans for AMR in indicator and zoonotic bacteria in the major livestock production sectors (pig, poultry and cattle). These plans have been managed by the ANSES in collaboration with the DDPP and public laboratories (LVD) since 1999 for broilers, 2000 for pigs and 2002 for cattle. These plans are still ongoing, but have been progressively abandoned for *Salmonella* screening (in 2004 for broilers and pigs and in 2008 for cattle) due to low prevalence and therefore an insufficient number of isolated strains.

Since 2008, surveillance of AMR in *Salmonella* has been implemented in the primary stages as recommended by the European Commission Decision of 12 June 2007 (C(2007) 2421) , beginning with laying hens in 2008. The strains tested for AMR come from the continuous monitoring with an upper limit of 170 per year and per livestock sector. Data have been also collected from baseline studies organised at this stage both in the poultry and pig production. For the food sector, recent data have been collected under the national control and surveillance plans.

This surveillance activity has been included in the working plan of the NRL for AMR following technical recommendations of the EFSA for European data harmonisation. It is to lead to information on antimicrobial resistance in *Salmonella* serotypes per animal species or food category.

Thus, the active institutional surveillance system provides national data on the prevalence of *Salmonella* per serotype, with the flock or herd as the epidemiological unit for food animals and the batch or carcass for food. Depending on the study, the target populations include breeding animals, food production animals or food categories, covering the whole food chain. The various studies are based on randomly chosen samples, which are generally stratified according to the size of the farm or slaughterhouse and designed to be representative of national production for food animals and of target risk items for food. The continuous mandatory monitoring is exhaustive for the targeted livestock sectors. Long-term, continuous mandatory monitoring makes it possible to analyse trends in prevalence and emergence of particular serotypes or resistance profiles, whereas cross-sectional studies (baseline studies, control plans and surveillance plans) give isolated assessments of prevalence. The laboratories involved in this surveillance follow quality assurance procedures and the NRL organizes inter-laboratory proficiency trials to evaluate the ability of laboratories to perform the methods. Data for baseline studies are analysed either by the DGAL or the NRL. The data collected in the context of harmonised European surveillance are further analysed and published by the EFSA in annual community summary reports. The data are all published through internal communication channels and, for food data, on the Ministry of Agriculture's website.

Passive surveillance system (Table 4)

For the past several years, the ANSES (ex-AFSSA) has been managing several passive surveillance networks that provide data on *Salmonella* isolated from several sectors of the agri-food chain.

The network of the epidemiological observatory in the poultry farming (RNOEA) was created in 1987 and is managed by the ANSES Ploufragan Laboratory (17). The objective is to provide veterinarians with epidemiological information on diseases observed in poultry, to follow trends and detect emergence. This network issues alerts for major diseases in poultry. The available data for *Salmonella* will involve the distribution of serotypes isolated from both diseased and healthy animals in poultry.

The French network for AMR surveillance system in veterinary pathogens (RESAPATH) was created in 1982. This network is managed by the coordinated action of two ANSES Laboratories, Lyon (for cattle and small ruminants) and Ploufragan (for poultry and pigs) (18, 19). It aims to give scientific and technical advice to laboratories and veterinarians on AMR in pathogenic bacteria, including *Salmonella*, isolated from food-producing animals exhibiting clinical signs. Data on trends and emergence of antimicrobial resistance in pathogenic *Salmonella* are produced by this network.

The "*Salmonella*" Network was created in 1997. This network is managed by the ANSES Maisons-Alfort Laboratory and collects strains of non-human origin. Its objectives are to provide technical advice for *Salmonella* serotyping, to determine national temporal trends on *Salmonella* serotypes isolated in the food chain and to detect emerging or unusual events (20). Data available involve the distribution of serotypes and the AMR profiles of 13 to 14,000 non-human strains of *Salmonella* per year, covering the whole food chain (from animals to food products, including feed).

The networks' partners are private and public veterinary laboratories. In addition, veterinarians provide case records to the RNOEA. Microbial analyses are multicentric (partly performed by ANSES for the *Salmonella* Network); only the results of biological tests or diagnoses are reported to the RNOEA or RESAPATH. However, analyses are validated by inter-laboratory trials organised annually by ANSES, for the *Salmonella* Network (serotyping) and RESAPATH (antimicrobial resistance). In all cases, epidemiological data are collected on the original sample (geographical data, date of sampling, product description). Duplicates should be further controlled. For the *Salmonella* Network, AMR testing is performed on non duplicate isolates. Duplicate isolates are here defined as coming from the same parcel sent by mail, belonging to the same serotype and sharing similar epidemiological data. For RESAPATH, duplicate data are defined for strains isolated from the same animal or flock, the same sampling date and the same serotype and antibiotype. Descriptive data

	Salmonella Network	RESAPATH	RNOEA
Coordinator	ANSES	ANSES	ANSES
Objectives	Analyses of spatio-temporal trends of *Salmonella* in the whole food chain and detection of unusual events	Analyses of spatio-temporal trends and detection of emergence of antimicrobial resistance in veterinary pathogenic bacteria	Analyses of spatio-temporal trends and detection of emergence of poultry diseases
Means of data collection	Event based surveillance	Event based surveillance	Event based surveillance
Scope of surveillance	National	National	National
Monitoring period	Continuous, since 1997	Continuous, since 1982	Continuous, since 1987
Pivotal variable	Strain number per serotype	Strain number per livestock sector and pathology	Notification number (contaminated flocks and/or notifications of diagnosed disease)
Disease focus	*Salmonella* specific	Multi-pathogens	Multi-pathogens
Design	Descriptive	Descriptive (+ cross-sectional studies)	Descriptive
Temporality	Trends	Trends	Trends
Availability of non pivotal information	Yes	Yes	Yes
Way of selection	Non-random	Non-random	Non-random
Source of data	Laboratory investigation records and biological specimen banks based on opportunistic collection	Laboratory investigation records based on opportunistic collection	Vet and laboratory investigation records based on opportunistic collection
Coverage of the population	97% and 77%of public and private veterinary laboratories, respectively	59 laboratories in 52 *départements*	60 veterinarians and laboratories
Duplication of data	Not controlled	Not controlled	Controlled
Target population	All livestock sectors, foodstuffs and environment	All animals sampled for an antibiogram	National poultry production
Study population	Strains from animals, foodstuffs and environment analysed by participating laboratories	Animals sampled for an antibiogram and analysed by the network partner laboratories (food animals and pets)	Poultry flocks traced by veterinarians or laboratories
Epidemiological unit	Strain	Strain	Flock
Case definition	*Salmonella* strain identified in the sample	Strain isolated from an ill animal	Flock affected by a disease and notified by veterinarians
Laboratory testing	Identification / serotyping: laboratories and ANSES AMR and PFGE: ANSES	Identification / serotyping / AMR: participating laboratories	Identification / serotyping: participating laboratories
Data collection and management	ANSES –LSAl/CEB	ANSES Lyon and Ploufragan	ANSES Ploufragan
Analytical methodologies	Descriptive statistical analyses, unusual event detection	Descriptive statistical analyses + specific	Descriptive statistical analyses
Quality assurance	Quality assurance as implemented at LSAL Accreditation for serotyping, Inter-laboratory trial for serotyping	Quality assurance as implemented in ANSES laboratories, inter-laboratory trials for AMR testing	Standardisation of poultry disease diagnosis through common guidelines No analytical standardisation
Sources of bias	Willingness of the laboratories to participate Impact of regulations Investigator bias	Willingness of the laboratories to participate Detection bias Investigator bias	Willingness of the laboratories to participate Declaration bias Investigator bias Impact of regulations
Reporting	Quarterly and annual reports to network partners, unusual event reporting	Annual reports to network partners	Bi-monthly and annual reports to network partners

TABLE IV: Non-human event based surveillance in 2008.

are reported to the partners of the networks on a regular basis. Detection of unusual events is regularly performed on the number of isolates per serotype in the *Salmonella* Network.

This description of the public networks available for professional stakeholders and scientists does not preclude the existence of other databases in France maintained by and available to private operators on specific topics. For example, specialised private networks focus on *Salmonella* isolation results in feedstuffs (Qualimat network) and on *Salmonella* strains isolated in the pig sector (http://www.ifip.asso.fr/actu/pdf/MA_aval.pdf).

Discussion / Conclusion

The surveillance of the agri-food sector in France relies on an integrated food-chain system implemented under national regulations, according to European dispositions, supplemented by laboratory-based passive networks. National regulations offer a solid foundation for this surveillance, promoting harmonisation of methodologies, systematic sampling at the farm level in the main livestock sectors, risk-based surveillance of food within the framework of the "Food Law" (21) and inte-

gration of AMR in the monitoring systems. The importance of harmonising the surveillance tools (typing tools, analyses, etc.) has been emphasized by many authors (22-24). In Europe, harmonisation relies on the NRLs, coordinated by the EU-RLs through their technical support and the inter-laboratory proficiency trials they organise (25). The final objective of this *Salmonella* surveillance system is to contribute to the reduction of the incidence of human cases within a farm-to-table approach, to limit contamination at each stage in the food chain. This is of utmost importance because, small improvements in animal health can lead to a significant reduction in human cases (26) and because there is no failsafe way of ensuring the safety of food items at any given point in the food supply chain (27).

LIMITATIONS AND POTENTIAL DRAWBACKS

Many of the usual limits and structural threats encountered in public health surveillance systems cannot be avoided in the French *Salmonella* surveillance system.

The burden of salmonellosis is difficult to assess and is probably underestimated, as the reporting of human diseases in France is based on mandatory notification of foodborne outbreaks and the centralisation of passive laboratory results for sporadic cases. Both types of surveillance system, as most foodborne and declarative surveillance systems, are subject to under-reporting and under-diagnosis (28) with the cases reported and filed being only a part of the effective burden (29). In 1995, a capture-recapture method has estimated that the mandatory reporting of foodborne outbreaks with a confirmed case of *Salmonella* represents only 15% of all cases (30). This may be linked to complex bureaucratic procedures, patients or doctors reluctant to notify or unaware of the obligation to notify (31) and the unknown aetiology of most reported outbreaks (30). Similarly, the extent of *Salmonella* animal carriage or food contamination is not precisely known. Mandatory exhaustive control plans and prevalence studies do not cover all species. Poultry, are surveyed by surveillance programme at the farm and slaughterhouse level, pigs, cattle and sheep are inspected by cross sectional surveys at the slaughterhouse level, but other food animals can contribute to the transmission of *Salmonella* such as fish, ducks (32) or dairy animals and other products (33, 34). No representative data are available for such sources. For sources that are included in prevalence studies or an exhaustive mandatory control plan, small herds are not monitored and investigator bias cannot be completely eliminated despite strong harmonisation efforts.

Meanwhile, almost all sources are potentially covered by the passive surveillance, but passive systems suffer from a lack of representativeness and reporting delay. The willingness of laboratories to participate in the networks can interfere, and selection bias can affect the human cases reported or the strains collected. In addition to biases due to the passive structure of networks, their multicentric design can lead to investigator bias. As an example, the epidemiological information associated with strains is of unequal quality. As a result, the management of duplicates can be difficult. All these weaknesses are highly dependent on the operational quality of the networks. These networks must therefore be evaluated to determine the reliability of the results (35).

In France, there are many actors involved in the integrated surveillance of *Salmonella*. This makes the data centralisation difficult and leads to heterogeneous data of sometimes unequal quality. For example, the epidemiological units and the subtyping tools used are numerous. This can hamper collaborative studies and data cross-analysis. Moreover, this "multiple-head" system has a non-negligible inertia in a context where there is an obligation to comply with European regulations and prevalence and exposure rates that are in constant flux. Thus, a few livestock sectors, known for their potentially high prevalence and exposure rates are well monitored. But owing to the control programmes implemented, their prevalence levels have been reduced. In contrast, other food animals (such as ducks, minor species, etc.) which are consumed to a lesser, but nonetheless tangible extent, may present high prevalence rates and do not benefit from the active surveillance system.

STRENGTHS AND OPPORTUNITIES

Some of the characteristics of the French surveillance system, despite the inherent biases presented above, can also confer strengths to the system.

The multicentre surveillance system, made up of different independent networks and organisations, allows for a high level of specialisation of each one with a clear definition of objectives, a strong participant involvement and good knowledge of the data and their characteristics. Each network has solid experience in its field. Given that they have been established for a long time, these networks are stable and reliable. The networks of laboratories participating in passive surveillance systems such as those of the NRC or the ANSES have remained stable over the years and cover the whole country. The resulting databases are therefore appropriate for detecting trends or unusual events for both sporadic and outbreak-related cases and food source contamination.

Given its flexible organisation, the surveillance system can adapt to new developments through several independent tools. For example, the active AMR surveillance system was suspended for *Salmonella* in 2002 for poultry and pigs in 2002 and more recently for cattle. Indeed, too few strains were collected in the frame of these representative sampling plans due to the low prevalence rates. However, data could be collected through an exhaustive surveillance programme set up for poultry production since 2008 and through the passive *Salmonella* Network which collects *Salmonella* strains in all sectors of the food chain.

Specialised passive networks can also adapt to changing prevalence rates as in the case of the clinical salmonellosis in adult cattle network (RESSAB). RESSAB, created in 1996, was run by the AFSSA until 2007. The objectives were to monitor the incidence of salmonellosis associated with intestinal or abortive symptoms in adult cattle and to identify associated serotypes and antimicrobial resistance (36). This network made information available on the prevalence of laboratory-confirmed clinical salmonellosis in cattle, but ceased its activity in 2007 when incidence became too low.

In addition, although surveillance tools are independent, there is close collaboration and harmonisation such as between

the NRC and the InVS, and with the *Salmonella* Network, reinforcing the complementarities of their databases (37).

The combination of active and passive surveillance tools also fosters complementarities. In a context of limited public funding and resource allocation, active surveillance can not cover all sectors annually. This incompleteness of surveillance is partly addressed by the coexisting permanent passive system. Likewise, the national *Salmonella* surveillance system described here can also collect data belonging to non-food animal-associated sources and cases. Official surveillance of the potential non-animal food sources, such as vegetables (38), is partly performed by the General Directorate for Competition, Consumer Affairs and Fraud Control through annual surveillance and control plans. Non-food sources are also to be considered since an estimated 5% of the transmission of *Salmonella* is not food-mediated (39). Pets and especially exotic pets are known to be contamination sources (40-43) and human-to-human transmission has also been described (44). These sources are not actively monitored, but as for non-animal food sources, some data are available through the *Salmonella* Network, which indeed offers a useful alternative to active surveillance for these sources. Finally, there are some private initiatives such as Qualimat (http://www.qualimat.org/), an association which runs a self-inspection plan for *Salmonella* in raw materials with the participation of the feed manufacturers, and the PFGE profiles database managed by the "Institut du Porc" (http://www.ifip.asso.fr/actu/pdf/MA_aval.pdf). This demonstrates that there is global concern about *Salmonella* and a will to monitor and to control it in all sectors, albeit imperfectly, but efficiently. For these reasons, the multiplicity of systems and organisations can be a positive point.

The success of integrated surveillance at a national level depends on the availability of high-quality, accessible and comparable data used for meaningful analysis and reporting. This type of effective surveillance system should improve the scientific basis for implementing management measures as well as impact assessment and risk analysis.

Thus, the issues to be addressed by a surveillance system are diverse: detection of outbreaks, burden of illness and its financial cost, prevention, impact assessment of interventions, microbiological risk assessment (45). Close collaboration between the various organisations involved in surveillance, public health and food safety authorities and the harmonisation of methodologies between the public health and agri-food sectors is a key point in addressing most of these issues (1, 22, 23) and seems to be successful in France (46-48).

While passive networks often suffer from reporting delays and selection biases, their daily updated computerised databases are well suited for detecting and issuing alerts. The NRC performs weekly unusual event detection through time-series analyses on its database. This allows the implicated public health authorities to be informed quickly to initiate the investigation of the outbreaks detected. The epidemiological investigations coordinated by the InVS rely on combined data across agri-food and public health surveillance programmes (namely the NRC and the *Salmonella* Network), which is made possible through the harmonisation of laboratory methodologies. The *Salmonella* Network is implementing a similar alert approach (49), on contamination in the early food chain onwards which could allow earlier warnings and thus possibly prevent outbreaks.

Sporadic cases require a different approach, based on prevention and risk-based interventions. Attributing the cases to the main food-animal reservoirs is of utmost importance in detecting and assessing the impact of such interventions (1, 22, 50). Several approaches can be used to perform attribution (51). In the case of sporadic case attribution, it is necessary to have access to representative data from the agri-food sector. A microbial subtyping attribution project is currently in progress in France (52). This type of approach can be implemented thanks to the active collaboration of all the different surveillance partners.

Based on the information provided by the different surveillance systems, management actions are implemented and are to be evaluated regularly according to outcome indicators. In France, interventions have been enforced at the farm level. The first line of action is the prevalence in flocks, but the real objective is a reduction in the number of human cases. Within the framework of European regulations, continuous control programmes are implemented with prevalence reduction targets defined according to the livestock sector involved. These results show that the programmes are efficient and the sanitary conditions of chicken breeding flocks are satisfactory. Furthermore, the impact on human cases of the national control programme implemented in chicken breeding flocks from 1998 onwards has been evaluated through a time-series analysis (53), using NRC data. A 33% decrease in prevalence in flocks was reported, with a significant decrease in human cases between 1998 and 2003, up to 21% for cases associated with the serotype Enteritidis.

Finally, collaboration also operates on an international level. The French public health and food safety authorities cooperate at the European level with the ECDC and EFSA, and the NRC is the WHO collaborating centre for reference and research on *Salmonella*.

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