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Review

Meat Safety from Farm to Slaughter—Risk-Based Control of *Yersinia enterocolitica* and *Toxoplasma gondii*

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Abstract: The implementation of the traditional meat safety control system has significantly contributed to increasing food safety and public health protection. However, several biological hazards have emerged in meat production, requiring a comprehensive approach to their control, as traditional methods of meat inspection at the slaughterhouse are not able to detect them. While national control programs exist for the most important meat-related hazards, similar data are still lacking for certain neglected threats, such as *Yersinia enterocolitica* or *Toxoplasma gondii*. The obstacle in controlling these hazards in the meat chain is their presence in latently infected, asymptomatic animals. Their effective control can only be achieved through systematic preventive measures, surveillance or monitoring, and antimicrobial interventions on farms and in slaughterhouses. To establish such a system, it is important to collect all relevant data on hazard-related epidemiological indicators from the meat chain, which should provide relevant guidance for interventions at the harvest and post-harvest stage. The proposed approach is expected to improve the existing system and provide many opportunities to improve food safety and public health.

1. Introduction

Different husbandry systems of farm animals are burdened with specific biological and chemical hazards, which are transmitted throughout the meat production chain from the farm to the consumer [1]. In the past, appropriate preventive measures and control systems were developed on the basis of systematic hazard analyzes and designed according to epidemiological conditions at specific times. For example, at the beginning of veterinary controls on farm animal health and meat safety (19th century), controls were already risk-based and focused on zoonoses such as tuberculosis, cysticercosis, or trichinosis [2]. Nowadays, due to systematic controls and the implementation of veterinary and hygiene measures, these zoonoses occur less frequently and the risk is negligible [3]. However, this is not equally true for all parts of the world [4–7].

Recently, "new" biological hazards have emerged in livestock and meat production, requiring a comprehensive approach to their control and monitoring. These hazards existed before, but prevention and control measures did not comprehensively address them [8,9]. Specifically, the safety of meat is mainly threatened by the so-called invisible hazards, i.e., biological and chemical contaminants such as bacteria, viruses, parasites, toxins, residues of veterinary drugs, environmental contaminants, etc., which do not cause clinical symptoms or visible changes in the meat or animal organs [1]. Traditional methods of meat inspection in slaughterhouses are not able to detect these hazards, which requires a more risk-based approach to reduce the risk to public health [8,9]. Therefore, the main biological hazards in meat production, both at farm and slaughterhouse level, are *Salmonella* spp., *Campylobacter* spp., *Yersinia enterocolitica*, verotoxic *Escherichia coli*, bacteria with ESBL/AmpC gene, *Trichinella*, and *Toxoplasma gondii* [10]. The obstacle in controlling these hazards in the meat chain is their presence in latently infected, asymptomatic animals. As detection of these

hazards on each individual carcass is impractical and unprofitable, their effective control is only possible through the application of a system of prevention and control measures on farms and in slaughterhouses [11,12].

In recent years, efforts have been made to establish a comprehensive integrated risk-based meat safety assurance system [9,13]. It is based on the identification of current public health risks and the implementation of control measures throughout the agri-food chain. In practice, this means that control and intervention measures are designed in slaughterhouses (harvest stage) according to previously identified hazards/risks on the farm (pre-harvest stage). The categorization of farms and slaughterhouses should help to better inform consumers about the level of safety on farms, which in turn may affect the practice of high-risk farms or slaughterhouses [9]. The categorization of farms and slaughter animals is based on food chain information (FCI) collected and recorded from the farm management system, surveillance, or monitoring programs and results of official controls [14,15]. These data guide the official veterinarian/risk manager in slaughterhouses when deciding on ante-mortem inspections, logistic slaughter, slaughter bans, visual or traditional meat inspection methods, decontamination procedures, and sampling for laboratory analysis. In the case of non-compliant data from the production chain on these hazards, risk reduction or elimination measures are chosen, such as decontamination of carcasses, freezing of meat, detailed post-mortem inspection, or additional laboratory testing [10,13]. Since the risk of bacterial pathogens in meat depends largely on the hygiene of the process between slaughterhouses [11], it is necessary to carry out risk categorization. In this way, improved meat safety is achieved in relation to the technology used in the slaughter process (Good Hygiene Practice, Good Manufacturing Practice) and, if necessary, the possibilities of decontamination technologies [11].

With regard to the listed priority biological hazards (pathogenic bacteria and parasites), the categorization of animals/farms should take into account the results of previous laboratory tests (if available) and adjust sampling and analysis plans according to trends [9,13]. Reliable data on certain prioritized threats, such as *Yersinia enterocolitica* or *Toxoplasma gondii* are still lacking at the farm/slaughterhouse level. The FCI needs to be complemented by Harmonized Epidemiological Indicators (HEIs), which provides the risk score of a specific part of the meat chain [14,15]. The purpose of this paper is to present the elements of a risk-based control system from farm to slaughterhouse, with a particular focus on *Y. enterocolitica* and *T. gondii* as examples of underestimated meat-borne hazards within the existing regulatory framework.

2. Biological Hazards in the Meat Chain

Bacterial intestinal pathogens have always been a challenge in meat hygiene, such as *Salmonella* spp., *Yersinia* spp., *Campylobacter* spp., *Listeria monocytogenes*, or *Escherichia coli* [1]. They are not physiologically present in the meat but get there during the slaughter processing of the animals, but also in the further course of handling and processing of meat by equipment, surfaces, and personnel [11,12]. Therefore, their finding on the meat (surface contamination) is due to their presence in slaughtered animals [1]. Recent systematic studies show that the prevalence of *Salmonella* and *Campylobacter* in broilers or pigs is over 20% and 50%, respectively, but it depends on the type of samples (from animals or the environment—the farm), the rearing method, and the area of observation (Table 1). The seroprevalence of *Y. enterocolitica* is highest in pigs and poses a greater meat safety challenge than *Salmonella* in some countries [15]. Shiga toxin-producing *E. coli* (STEC) has also shown an upward trend among foodborne zoonoses in recent years, but there are few data on its prevalence on farms. Regarding the results of national programs for the surveillance of specific pathogens of meat-borne diseases, such as in the EU, there are significantly lower prevalence compared to global/continental scientific studies (Table 2). The number of EU countries reporting the results of their on-farm bacterial surveillance programs is inconsistent and varies considerably across species. This is particularly true at the slaughter stage, where data are most complete only for *Salmonella* in pigs, and there

are almost no data for the prevalence of *Yersinia* and STEC on carcasses of slaughtered animals (Table 3). Of the parasitic zoonoses, *Toxoplasma gondii* is considered a priority hazard in the meat production chain. This is supported by data on its high prevalence in pigs worldwide [16] and in ruminants and certain wildlife species [17]. National control programs exists for several prioritized meat-related hazards in many countries, but similar programs for *Y. enterocolitica* and *T. gondii* are missing [15].

Table 1. Recent studies on (sero)prevalence of main biological hazards in farm animals.

Animal Species	Biological Hazard	Sampling	Prevalence	Country, Reference
Broilers	*Salmonella* spp.	Environmental samples—boot sock, feces, litter, drag swab, feed, water, grass, soil, compost	22.9% (95% CI: 14.5–34.2%) and 19.9% (95% CI: 7.1–44.8%) for conventional and alternative samples, respectively	USA (systematic review), [18]
	Campylobacter spp.		15.8% (95% CI: 3–52%) and 52.8% (95% CI: 32.8–71.8%) for conventional and alternative samples, respectively	
Pigs, poultry, cattle, goat, sheep	*Salmonella* spp.	Gut samples	27.8% (95% CI 20.4–36.7); 40.2% (95% CI 32.7–48.2); 15.4% (95% CI 11.7–20.0); 16.8% (95% CI 11.4–24.6); 13.6% (95% CI 8.5–21.1)	Africa (systematic review), [19]
	Campylobacter spp.		15.4% (95% CI 8.4–26.6); 13.4% (95% CI 9.8–18.0); 4.5% (95% CI 2.9–6.9); 2.2% (95% CI 1.1–4.3); 4.5% (95% CI 2.8–7.2)	
Cattle	*Salmonella* spp.	Feces	9% (95% CI 7–11%)	Global (systematic review), [20]
Pigs	*Yersinia enterocolitica*	2353 meat juice samples, 259 farms	57% of pigs and 85% of farms	[15]
	Toxoplasma gondii		3% of pigs, 9% of farms	
Pigs	*Yersinia enterocolitica*	57 indoor fattening pig farms, serum	72.3%	[15]
	Toxoplasma gondii		<1%	
	Salmonella spp.		1.9–17.6%	
Pigs	Toxoplasma gondii	148,092 pigs from 47 countries	19% (95% CI: 17–22%)	Global (systematic review), [16]
Pigs, sheep, cattle, wild boars, moose	*Toxoplasma gondii*		6% in domestic pigs (CI 95%: 3–10%), 23% in sheep (CI 95%: 12–36%), 7% in cattle (CI 95%: 1–21%), 33% in wild boars (CI 95%: 26–41%), and 16% in moose (CI 95%: 10–23%)	Nordic-Baltic region in northern Europe (systematic review), [17]

Table 2. Official data on (sero)prevalence of main biological hazards in farm animal [21].

Biological Hazard	Animal Species	Sampling	Prevalence	Countries Reported the Data
Salmonella spp.	Broilers	National Control Programs, n = 361,974 flocks	3.48%, range by countries: 0–18.4%	29 EU countries
	Cattle	Feces, farm environmental samples; 25,687 cattle, 3962 herds	4.13% of animals and 0.88% of herds	13 EU countries
	Pigs	Caecum, feces, lymph nodes; 16,947 animals, 71,006 slaughter animal batch, 732 herds	0.97% in pigs, 53.2% in slaughter animal batch, 3.96% in herds	13 EU countries
Campylobacter spp.	Broilers	Caecum, n = 17,445 flocks/batch	22.18%	18 EU countries
	Turkey	Caecum, n = 1228	68.81%	5 EU countries
	Pigs	Feces, organs, n = 2504	2.12%	9 EU countries
	Cattle	Animal samples, n = 31,842	0.53%	12 EU countries
Yersinia enterocolitica	Pigs	Animal samples, n = 2354	0.43%	7 EU countries
	Domestic livestock other than pigs	Animal samples, n = 12,834	1.66%	6 EU countries
Toxoplasma gondii	Pigs	Blood, n = 263	22.05%	4 EU countries
	Sheep and goats	Blood, animal samples, n = 6818	5.47%	14 EU countries
	Cattle	Blood, animal samples, n = 159	27.7%	7 EU countries
STEC	Cattle	Feces, animal samples, n = 390	3.59%	2 EU countries
	Pigs	Feces, animal samples, n = 5	20%	2 EU countries
	Goats	Feces, animal samples, n = 5	40%	1 EU country

Table 3. Official data on prevalence of main biological hazards on carcasses at slaughter [21].

Biological Hazard	Animal Species	Sampling	Prevalence	Countries Reported the Data
Salmonella spp.	Broilers and turkey, chilled carcasses	Neck skin/carcass, n = 2381	15.08%	7 EU countries
	Cattle, sheep, goats and horses—carcasses before chilling	Carcass swabs 400 cm^2, n = 3848	0.55%	8 EU countries
	Pigs	Carcass swabs 100/400 cm^2, n = 149,962	1.62%	28 EU countries
Campylobacter spp.	Broilers, chilled carcasses	Neck skin/carcass, n = 3746 (PHC Reg. 2073)	35% (8.94% units with >1000 cfu)	10 EU countries
	Fresh broiler meat	1/10/25 g, n = 3621	27.9%	11 EU countries

Table 3. *Cont.*

Biological Hazard	Animal Species	Sampling	Prevalence	Countries Reported the Data
Yersinia enterocolitica	Pigs	Carcass swabs, n = 115	0.87%	1 EU country
STEC	Broilers	Carcass meat, 25 g, n = 31	22.58%	1 EU country
	Goats	Carcass swabs, 400 cm^2, n = 3	33.3%	1 EU country
	Horses, rabbits	Carcass swabs, 400 cm^2, n = 9	0.0%	1 EU country

3. Underestimated Biological Hazards in Meat Chain Control

3.1. Yersinia enterocolitica

Yersinia enterocolitica is an important and often neglected pathogenic microorganism in veterinary public health and meat hygiene [12]. Human yersiniosis is one of the leading foodborne zoonoses and has been declared as the fourth zoonosis after campylobacteriosis, salmonellosis, and Shiga toxin-producing *E. coli* infection, according to EU data [21]. Although bacterial transmission to humans usually occurs through raw or undercooked food or water, some infections have been reported under the low level of personal hygiene [12,15]. Infection with pathogenic *Y. enterocolitica* is usually manifested by milder gastrointestinal symptoms that usually do not require treatment. Therefore, the actual number of infected individuals is believed to be much higher than the number of reported cases, so that the public health importance of this bacterium has been underestimated over time [12].

3.1.1. Farm Risk Factors and Serological Testing

Domestic pigs are the most important carriers of pathogenic *Y. enterocolitica* strains as well as a source of contamination of meat intended for human consumption [12]. At the farm level, it is estimated that pathogen prevalence is higher in conventional intensive farming systems than in organic extensive farming systems [22] and may be seasonal [23]. Regarding the colonization and occurrence of *Y. enterocolitica* in different categories of pigs, most studies indicate persistence of the risk in fattening pigs. Fecal shedding of pathogens begins at one to three months of age and peaks at two to five months of age. After this age, fecal incidence decreases, but pigs remain seropositive for a longer period of time [24]. It is estimated that 35–70% of swine herds and 45–100% of individual finishing pigs are carriers of *Y. enterocolitica* [25]. Our recent study (unpublished) showed that despite the same (highest) biosecurity levels in integrated pig farms, the prevalence of pathogenic *Y. enterocolitica* was significantly different between farms, suggesting that risk factors for the occurrence of the pathogen in tonsils may be related to harvest level [26]. In contrast to integrated farming systems, a significant influence of biosecurity level on pathogen prevalence was found in small family farms, i.e., the lower the biosecurity level of the farm, the higher the pathogen prevalence [26].

In terms of risk factors, Virtanen et al. [27] found that infection (carrier status) and excretion of *Y. enterocolitica* in feces was prevented by the use of municipal water, purchase of pig feed from a single trusted supplier and organic production (i.e., protective factor). The risk factors for the excretion of *Y. enterocolitica* in feces are carrier status of the pathogen on tonsils, purchase of pig feed from multiple suppliers, feeding pigs before transport to slaughterhouse, and snout contact. Vilar et al. [28] also claim that the prevalence of *Y. enterocolitica* in pigs can be reduced by using only municipal water and an all-in/all-out system, while a lack of bedding and the purchase of piglets from multiple farms are risk factors.

To categorize farms in terms of *Yersinia* risk, the use of serological monitoring prior to slaughter has been strongly recommended in recent years [29]. Felin et al. [30] re-

ported strong correlation between seropositivity to *Salmonella* and *Yersinia* in fattening pigs. Moreover, the housing system was also important factor for *Yersinia* seroprevalence [30]. Serological results in FCI give the possibility for the slaughterhouse to risk-rank farms according to the risk of shedding *Yersinia*, and slaughter the pigs from high-risk farms at the end of the day and use hot water decontamination for these carcasses [15].

3.1.2. Prevalence of Pathogen in Pigs

Pigs are asymptomatic carriers of strains pathogenic to humans, mainly biotype 4 (serotype O:3) and less frequently biotype 2 (serotype O:9 and O:5.27). They are found in the oral cavity, particularly in the tonsils, submandibular lymph nodes, tongue, and intestines and feces [31]. It is common to find strains of bioserotype 4/O:3 on the surface of slaughtered carcasses due to fecal contamination, intestinal, and tonsil contents during slaughter processing [32]. The detection of *Y. enterocolitica* in the tonsils depends on numerous factors, such as the time of infection (on-farm, during transport, in the slaughterhouse barn) or slaughterhouse practices (cross-contamination). For example, the procedures during housing before slaughter are very important for the spread of pathogens between groups of pigs in lairage [29]. Nowak et al. [33] recorded a higher prevalence of *Y. enterocolitica*, particularly in the tonsils, in pigs slaughtered at the end of the day than in pigs slaughtered at the beginning. This suggests the contamination of pigs brought to slaughter from different sources, and contamination occurred via feces from previously dormant pigs in the herd. Indeed, after oral infection, the bacteria can be detected in the appendix and lymph nodes within only three hours [29,33].

The prevalence of *Y. enterocolitica* in the tonsils of slaughtered pigs varies widely in Europe, ranging from 1.8 to 93% [34,35]. The highest recovery rate of the pathogen is found in tonsils, and it is lower in intestines or on pig carcasses. In the UK, the prevalence of *Y. enterocolitica* in tonsils was 28.7%, while in carcasses, it was only 1.8% [36]. In Belgian slaughterhouses, 55.1% of tonsil samples, 25.1% of fecal samples, and 39.1% of carcasses were positive. The incidence of the pathogens was highest in the tonsil region (29%) and much lower in the pelvic and sternum regions (7–16%) [37]. Centorame et al. [38] reported a relatively low prevalence of 9.31% in the tonsils, but the dominance of bioserotype 4/O:3 (95.74%) indicates the importance of pigs as natural reservoirs for human yersiniosis. In Brazil, a prevalence of 25.2% was reported from pig tonsils with only two pathogenic strains, confirming high variability in pathogen persistence between countries [39]. In a Croatian study [32], *Y. enterocolitica* bioserotype 4/O:3 strains were recovered from 33.3% of tonsils and 10.25% of mandibular lymph nodes. A recent study from the same pig farming system and slaughterhouses in Croatia revealed a prevalence of 43% of pathogenic *Y. enterocolitica* 4/O:3 in pig tonsils [26]. The above survey reports indicate high variability in prevalence between studies, which is possibly due to differences in farm management, sampling methods, hygienic practices at slaughter, and, in particular, methods of pathogen isolation and detection.

3.1.3. Meat Contamination at Slaughter and Meat Processing

Regarding the risk of meat contamination during slaughter, Vilar et al. [28] claim that the presence of *Y. enterocolitica* in the intestines, tonsils, and offal are the main risk factors, which also leads to a higher probability of cross-contamination. The prevention of meat contamination during slaughter should be based on standard operative procedures such as bunging/rectum tying and removal of the head together with the tonsils [40]. Removal of the tonsils is a critical step as, for example, the parts of the tonsils remaining in the throat after evisceration can be a major cause of the spread of pathogens from lymphatic to muscle tissue [32,41,42]. It is also suggested to partially remove the viscera by leaving the tongue and tonsils on the halves and omitting the incision of the mandibular lymph nodes. In countries such as Denmark and Canada, carcass halves are decontaminated with hot water or steam to reduce the incidence of *Y. enterocolitica* [43].

With regard to slaughter techniques and possible failures in processing hygiene, contamination with pathogens is expected to occur mainly in the meat of the neck, head, tongue and throat region, less so in the carcass [44,45]. Martins et al. [46] isolated *Y. enterocolitica* from the tonsils and lymph nodes of pigs but not from the environmental samples or from the meat after carcass splitting. However, the presence of pathogenic *Y. enterocolitica*, even in low numbers, is a risk factor for consumers because of its ability to grow at lower temperatures, as well as temperature abuse during chilling [47,48]. In this regard, minced meat, characterized by high microbiological risk, is a possible source of *Y. enterocolitica* [49]. Visnubhatla et al. [50] recorded a high level of contamination of minced beef and pork with the pathogen *Y. enterocolitica* up to 6 log CFU/g, which poses a risk to the consumer. Recently, Ferl et al. [51] reported *Y. enterocolitica* contamination in minced pork (22.6%, N = 62) and seasoned minced meat (11.5%). Similarly, studies from Argentina, India, or Malesia indicate a higher prevalence of pathogenic *Y. enterocolitica* in fresh pork products on the market, but these results are highly variable and depend on risk factors such as the hygiene level of slaughter or farming practices [52–54].

3.2. Toxoplasma gondii

Toxoplasmosis is a worldwide zoonosis and one of the most common meat-borne parasitic diseases [12,16]. Recently, Aguirre et al. [55] presented the One Health approach to toxoplasmosis, which is one of the leading causes of death in the USA and has a high seroprevalence in humans (up to 90% in countries with low sanitary measures) [55]. Humans can become infected with the parasite via ingestion of oocysts directly from soil or in contaminated food or water; via ingestion of tissue cysts in uncooked/raw infected meat; or vertically from mother to child during primary infection in pregnancy [56]. However, it is known that consumption of undercooked meat is the most important factor [57]. In Europe, pork is generally considered the main source of invasions, while studies in Norway and France have shown that lamb is a more significant risk factor [58]. However, there is no official requirement for surveillance or control of *T. gondii* in meat-producing animals. Given the high prevalence and public health importance of *T. gondii*, it is necessary to establish an effective system to control this zoonosis in the meat production chain [12,16]. In the first place, the prevention of toxoplasmosis should be based on comprehensive control at the level of primary production (farm) and at the slaughterhouse, together with deactivation processes in meat processing [13]. To improve food safety, the European Food Safety Authority (EFSA) recommends the review of biosecurity measures in conventional finishing farms and serology in different types of herds to identify high-risk farms and use them within food chain information system [10,58].

3.2.1. Serological Testing—Pre-Harvest Control

The global seroprevalence of toxoplasmosis in pigs is estimated to 19%, and it is higher in free ranged systems [16]. Contrary, seroprevalence is lowest in intensive pig farming [59]. Serological methods are considered the primary method for diagnosing toxoplasmosis because it is asymptomatic in pigs and the cysts are too small to be detected during meat inspection at the slaughterhouse. To date, serological tests are regularly used to detect exposure in pigs and seroprevalence in general, both in pigs and other animals and in humans [12]. Serological testing for porcine toxoplasmosis in a slaughterhouse has proven to be the most practical method to obtain risk data from the farm and to take further control measures accordingly [15]. In particular, EFSA recommends serological testing of fattening pigs kept in uncontrolled housing systems [43].

Serology can only be used to assess the risk of infection to humans if there is a correlation between seroprevalence and the presence of cysts in meat. Opsteegh et al. [60] investigated this correlation for major domestic animal species and estimated that the probability of detection of parasites in seropositive animals was highest in pigs (58.8%), followed by chickens (53.4%), sheep, and goats (39.4% and 35.0%), and it was the lowest in horses and cattle. These data suggest that the correlation between antibody detection

against *T. gondii* and direct parasite detection is high in pigs, small ruminants, and chickens. In these species, the use of serology can help determine the risk to the consumer, but it may not be as useful in other species, such as horses and cattle. In addition, a seronegative result does not necessarily mean that the meat is free of *T. gondii*. Therefore, an integrated approach combining serology with molecular techniques would provide a multilevel understanding of the epidemiology of the parasite, as molecular detection provides additional information on the risk of meat consumption [61]. In studies by Jurankova et al. [62], the brain, heart, and lungs were the preferred sites for *T. gondii* cysts in experimentally infected pigs.

Different serological methods were used to detect IgG antibodies in pig serum and meat juice. Meat juice is commonly used because it is readily available at slaughter and can also be used to detect other zoonotic diseases such as salmonellosis, yersiniosis, and trichinosis [43]. It should be noted that IgG antibody levels are lower in meat juice compared to serum, so it is necessary to use a lower dilution factor for meat juice samples. Antibodies usually persist until the time of slaughter [63], but the immune response cannot be measured immediately after infection. Sometimes, an animal's immune system is unable to produce a measurable immune response despite carrying a pathogen. Therefore, serological methods are not always suitable for testing individual carcasses as part of a food safety assessment [16,29,30]. However, Felin et al. [15] investigated the seroprevalence of fattening pigs for *T. gondii* to assess the feasibility of serological surveillance in the slaughterhouse and the usability of the results as part of the FCI. Although the seroprevalence of *T. gondii* was generally low, some farms were found with 100% seroprevalence. Serological surveillance in this case would allow the identification of farms where existing biosecurity measures should be introduced and improved. These farms should be visited and advised by veterinarians to improve biosecurity measures, reduce risk, and increase the safety of meat for consumers. Carcasses of pigs from such high-risk holdings should be frozen or subjected to heat treatment [12].

3.2.2. Controls at the Slaughterhouse and during Meat Processing

Toxoplasma gondii is considered a priority risk in meat inspection of pigs, farmed game (wild boar, deer), sheep, and goats [12]. It is impossible to detect the risk of *T. gondii* through the traditional way of inspection in slaughterhouses [10]; therefore, additional (pre-)testing in the meat chain is needed. Based on the collected data on the hazards in the production chain (e.g., serological testing of animals), the necessary measures are selected to reduce or eliminate the risks in the meat production chain, such as heat treatment and freezing of meat [64].

Several processing methods can be used to decontaminate meat containing bradyzoites of *T. gondii* [65]. Heat treatment is the safest method to inactivate the parasite [66]. It is recommended to cook pork at a temperature of 70 °C, and the meat should be cooked thoroughly until the internal temperature reaches 66 °C. Cooking temperature and avoidance of cross-contamination are considered the most important factors in preventing *T. gondii* infection from meat consumption [63]. Both cooking temperature and bradysoite concentration of *T. gondii* in muscle are the highest risk factors for transmission to humans [67]. Most cysts are inactivated by temperatures below −12 °C/2 days [13]. Gamma radiation has the same effect as high pressure treatment at 300 MPa or more [68]. The problem may be the effect of these methods on the color, texture, and flavor of the meat and therefore may be unattractive to the consumer. In addition, the use of gamma radiation and high-pressure processing may be restricted by legislation and may incur high costs [69]. As for cured meat products, most studies suggest that cysts of *T. gondii* are destroyed during salt curing, but the inactivation of these cysts depends on the maturation time, temperature of storage, and salt concentration in the curing process [70–73].

4. Food Chain Information and Epidemiological Indicators

A central role in the meat safety system is played by food chain information, which should provide relevant guidance for the management of a group of animals or a herd in relation to the prioritized biological hazards [12]. The usual information on health, drug treatment, nutrition, operational measures, etc. in the above context of the meat inspection system is not sufficient as it does not cover all the hazards and control measures discussed before, e.g., for *T. gondii* or *Y. enterocolitica* [15]. When carrying out inspection procedures, the official veterinarian shall take into account the certificates and attestations accompanying the animals and any declarations made by the veterinarian, including official and authorized veterinarians who have carried out controls at the level of primary production [2,3,15]. This information should help to increase food safety for consumers, as it would act as a link between the farm and the slaughterhouse [10].

However, in most European countries, there are currently no regular monitoring programs for the main meat-borne zoonoses on farms, except for salmonellosis in chicken broilers, turkey broilers, commercial chicken flocks, turkey and chicken breeding flocks and strains of *S.* Enteritidis, *S.* Typhimurium, *S.* Hadar, *S.* Infantis, and *S.* Virchow, in breeding flocks of chickens [21]. If these data from primary production are credible, complete, and applicable, they can greatly reduce the risk and hazards, i.e., increase the level of food safety [15]. Therefore, the categorization of risks in certain stages of production from farm to slaughterhouse should be enabled by Harmonized Epidemiological Indicators (HEIs) [12–14]. Thus, the risk of herds/flocks on the farm in terms of microbiological hazards can be assessed by monitoring the audit of the animal procurement system, monitoring husbandry practices and the presence/absence of target bacteria in the feces of the animals [12].

Monitoring of transport of slaughter animals and housing conditions at the slaughterhouse prior to slaughter provides information on the risk of a particular group of animals (batch). During slaughter processing, the risk is assessed by the bacteriological status of the carcass before and after skinning and before chilling. By microbiological testing after carcass chilling, we obtain data on the performance of the system in relation to the set targets (microbiological criteria for specific bacteria) on the carcass [9–13]. Accordingly, low-risk animals in relation to e.g., *Yersinia* are handled on a standard slaughter line that has a proven ability to ensure the achievement of carcass targets (e.g., absence of *Yersinia*) through good hygiene and production practices and the HACCP system. On the other hand, carcasses of animals from high-risk farms (e.g., seropositive to *Yersinia*) should be subjected to a decontamination process (steam, hot water) at the end of the slaughter line to reduce the potential risk. Where the risk of *Toxoplasma* is high, measures should include thermal treatment of the meat [9–13].

5. Conclusions

Nowadays, meat hygiene is confronted with new threats, making the veterinary profession even more important in the context of an integrated system for ensuring meat safety and a risk-based approach to official controls. In order to identify health risks, a comprehensive approach to meat production and inspection must incorporate knowledge of primary meat production and hygiene and all available information from the entire production system. In a safety assessment of meat, it is important to analyze data on the food chain (FCI), epidemiological indicators, herd health, animal welfare, and hygiene practices in slaughterhouses/farms. In this context, the importance of veterinarians at farm level is obvious, as is the flow of food chain information from farm to slaughterhouse and vice versa. Meat inspection is a logical extension with preventive measures and controls in primary production. However, even perfect management and prevention in primary production cannot guarantee reduced risk if hygiene and processing practices in slaughterhouses are poor. For both *Y. enterocolitica* and *T. gondii*, the control strategy should be based on epidemiological indicators and consequent intervention protocols to ensure safe meat for human consumption.

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