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"Meat Juice Multi-Serology" – A tool for the continuous improvement of herd health and food safety in the framework of the risk-based meat inspection of slaughter pigs

„Fleischsaftmultiserologie" – Werkzeug für einen kontinuierlichen Verbesserungsprozess der Herdengesundheit und der Lebensmittelsicherheit im Rahmen der risikoorientierten Schlachttier- und Fleischuntersuchung von Schlachtschweinen

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Summary

For implementing the risk-based meat inspection, a meaningful "food chain information" is an indispensible precondition. The objective of this study is to increase the informative value of the current food chain information by adding the meat juice multi-serology concept for providing better knowledge on the health status of pig herds for the food operators, veterinary authorities and pig producers. Serum and meat juice samples from the same pigs were tested for antibodies against seven pathogens: *Salmonella* spp., *Yersinia enterocolitica,* Trichinella, Toxoplasma gondii, *Mycoplasma hyopneumoniae,* Influenza A H1N1 and H3N2. The comparison of the ELISA results from serum and meat juice samples showed a good to excellent agreement. Meat juice samples from the same pig herds were tested again after 12 months for demonstrating changes in the herd profiles over time. This meat juice multi-serology for benchmarking pig herds in terms of seroprevalences can be expanded to any other pathogen (CSF-Virus, PHV-1, Hepatitis E Virus, etc.).

Keywords: Pre-harvest food safety, Monitoring, Slaughterhouse, Surveillance, early-warning system

Zusammenfassung

Bei der Einführung der risikoorientierten Schlachttier- und Fleischuntersuchung sind aussagekräftige Lebensmittelketteninformationen eine der wichtigsten Grundvoraussetzungen. Ziel dieser Studie ist eine Erhöhung der Aussagekraft der Lebensmittelketteninformation durch Ergänzung um das Konzept der Fleischsaftmultiserologie. Diese zusätzlichen Informationen zur Beurteilung der Herdengesundheit dienen gleichermaßen dem Lebensmittelunternehmer, der amtlichen Überwachung wie dem Landwirt. Serum- und Fleischsaftproben von denselben Schlachtschweinen wurden auf Antikörper gegen sieben Erreger untersucht: *Salmonella* spp., *Yersinia enterocolitica,* Trichinella spiralis, Toxoplasma gondii, *Mycoplasma hyopneumoniae,* Influenza A H1N1 and H3N2. Der Vergleich der ELISA-Ergebnisse mit Serum und Fleischsaft als Probenmaterial ergab eine gute bis exzellente Übereinstimmung. Nach zwölf Monaten wurden Fleischsaftproben von denselben Schweinebestände untersucht, um Veränderungen in den Herdenprofilen über die Zeit darzustellen. Das Konzept der Fleischsaftmultiserologie, welches für ein Benchmarking zum Vergleich der Seroprävalenzen untereinander genutzt werden kann, ist auf weitere Erreger dynamisch erweiterbar (z. B. KSP-Virus, PHV-1, Hepatitis E Virus).

Schlüsselwörter: Pre-harvest food safety, Monitoring, Schlachthof, Überwachung, Frühwarnsystem

Introduction

The new understanding of "One Health" (healthy animals and healthy people) and the new paradigm of assuring safe food (responsibility of food producers, prevention, risk-orientation, process-optimization, and continuous improvement) require new concepts for veterinary diagnostics. The focus of such new concepts supporting continuous improvement systems is proactively acquiring knowledge on the herd health status, early warning systems, surveillance, instead of diagnosing diseases and causes of death in single animals.

The present diagnostic system for food animals

The traditional diagnostic system for food animals has been reactive in terms of identifying animal disease (both notifiable and production diseases) at herd level only after clinical signs had occurred. The state veterinarians responsible for the control of notifiable diseases in livestock focus on identifying or excluding the causative agents of epidemics, based on reports about suspicious clinical or pathological symptoms at regional and national level. The farmers and veterinary practitioners focus on diagnosing the causes of production diseases for therapeutic measures at farm level. The slaughterhouse operators and official meat inspectors focus on identifying disease-related lesions relevant for food safety for protecting the consumer at slaughterhouse level.

These three diagnostic areas (1. notifiable diseases, 2. production diseases, and 3. food safety related diseases and zoonoses) have developed more or less independently of each other, which has led to a "fragmentation" of the present diagnostic system. As a rule there are on the one hand specialized and authorized diagnostic laboratories (mostly state laboratories) for notifiable diseases such as Classical Swine Fever and Pseudorabies, and there are on the other hand specialized diagnostic laboratories (mostly private laboratories) for production diseases caused by e. g. Influenza A viruses or *Mycoplasma hyopneumoniae.* Additionally, there are specialized diagnostic laboratories (both state and private laboratories) for zoonotic agents such as *Salmonella* spp. and Toxoplasma gondii, which either are part of the state food safety system or part of the growing self-monitoring in the framework of quality management systems run by the food producers. These three fragments of the present veterinary diagnostic system hardly communicate with each other. Furthermore, there is very little communication of diagnostic results along the food chain. Diagnostic information about farm animal diseases are rarely used in the decisions of meat inspectors; and vice versa diagnostic information about disease-related food safety risks are rarely used in the decisions of farmers and veterinary practitioners to optimize the health status of the herds of origin.

The need for restructuring the veterinary diagnostic system for food animals

The new European food safety concept with its basic Regulations (EC) No. 178/2002 (Anonym, 2002), and the so called "Hygiene Package" Regulations (EC) No. 852/2004, 853/2004, 854/2004 and 882/2004 (Anonym, 2004a, 2004b, 2004c), reflect the new paradigm targeted at improving not only food safety but also the health and welfare of all food animals (Hathaway and Richards, 1993). In contrast to the traditional sole responsibility of the state for providing safe food by final end product inspections, the core elements of these new European regulations are:

a) Strengthened responsibility of the food producer: All persons that are involved in the production of food of animal origin share the food producers' responsibility for food safety, animal health (notifiable and production diseases), and animal welfare, which is supervised by the official veterinary surveillance (i. e. public-private partnership). The food producers along the meat production chain are feed producers (farmers and feed mill operators), food animal producers (farmers supported by their consulting veterinarians), and slaughterhouse operators (supported by their quality management staff). The state still has the final responsibility, but not by inspecting the end products alone, but by enforcing the principle of the "control of the control". This principle has greatly contributed to the establishment of industry-driven self-monitoring systems with independent auditing and certification procedures.
b) Prevention and process-optimization: In contrast to the past paradigm of protecting the consumer by just condemning carcasses and organs during the official meat inspection at the slaughter line for preventing products "not fit for consumption" from entering the food chain, the new goal is to assure production processes at farm level that result in healthy animals for slaughter, which in turn result in carcasses that are "fit for consumption". The major tool for this is to implement systems for a continuous process optimization from feed to meat.
c) Risk-orientation and continuous improvement: Traditionally, official inspections of food production operations have been equally distributed at random with the same quantity and quality of the inspections, since no information on any differences in the compliance of the operations with current laws had been taken into account. The new approach recognizes that it is possible to gain information from existing data (feed mill and farm records, veterinary documentations on drug use, and slaughter check results) so that risk-oriented selections for inspecting operations are feasible: low-compliance (i. e. "high-risk") operations are inspected more frequently than full-compliance (i. e. "low-risk") operations. This principle leads "automatically" into incentive systems, which encourages continuous improvements.

Consequently, the future food production system demands for a new proactive diagnostic strategy for food animals. The overall task is to build up new concepts that serve the holistic requirements of the new European food safety philosophy. Such new diagnostic strategy should enable both the responsible food producers (from feed to food) and the official control system to make cost-effective and risk-oriented decisions that results in targeted, information-based actions for the continuous improvement of food safety, animal health and animal welfare on the basis of the growing role of public-private partnerships.

In the framework of the recent research of the Field Station for Epidemiology of the University of Veterinary Medicine Hannover on improving the so-called "food chain information" (Reg. [EC] 853 and 854/2004) the authors combined data from the farm such as the mortality rate, the drug use measured by the "animal treatment index" (Blaha et al., 2006), and the slaughter check results to provide the official meat inspection service with meaningful information for the risk-based meat inspection pro-

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cedure, the so-called "Herd Health Score" (Dickhaus et al.,2009). During these efforts it became obvious that there are general gaps in the knowledge about the health status and the zoonoses load of pig herds supplying pigs to the slaughterhouse (Meemken, 2006). This led to considerations how to collect data on the occurrence of especially the subclinical infections in pig herds with relevance for the safety of meat, but also for the health and well-being of the food animals in question.

The presented new concept of "meat juice multi-serology" follows the recommendations of the O.I.E. (Anonym, 2003) for the surveillance and monitoring of animal health not only by testing animals on the farm, but also by testing specimens taken at slaughter. The concept combines several serological tests for production diseases, zoonotic diseases, and notifiable diseases using meat pieces that can be taken at slaughter for producing meat juice. These meat juice samples can be collected on a permanent basis and easily assigned to the herds of origin, which results in a continuous flow of accumulating data per herd about all supplying pig herds. Such data sets will provide a) the official veterinarian, b) the farmer and his or her veterinarian, and c) the slaughterhouse operator with valuable information.

This approach can be easily implemented especially in countries with mandatory serological salmonella monitoring programmes for slaughter pigs such as Denmark, The Netherlands, Belgium, the UK and Germany.

In Germany, based on the national "Pig Salmonella Regulation" (Anonym, 2007), 60 random samples of meat juice (meat from the diaphragm pillar) per herd distributed over one year are taken as diagnostic specimens for salmonella antibody testing via an ELISA-test.

The core element of the presented "multi-serological" approach is to use the once taken meat juice samples not only for the salmonella monitoring programme, but also for as many as possible and desirable serological tests covering the three diagnostic areas described above. Measuring antibodies has the advantage that it gives an overview of agents that have occurred during the fattening period in contrast to the direct detection of antigen, which is only possible, if the agent is present and identifiable at the time of testing. By combining serological tests with relevance for production diseases, for zoonotic, and for notifiable diseases, a new multi-task diagnostic tool can be created for providing continuously updated serological herd profiles.

This paper describes the results of testing and validating the feasibility of using meat juice as specimen for an ongoing "multi-serological" herd health profiling for slaughter pig herds.

Methods

Selecting the tests

Analysing the array of currently available serological antibody ELISA tests for their potential usefulness for the planned "multi-serological" diagnostic tool, the following set of serological tests were selected for the study:

a) ELISA tests for production diseases caused by (licensed for blood serum only):
   - *Mycoplasma hyopneumoniae:* HerdChek® *M. hyo* (IDEXX, Westbrook, USA)
   - Swine Influenza Virus A H1N1: HerdChek® SIV H1N1 (IDEXX, Westbrook, USA)
   - Swine Influenza Virus A H3N2: HerdChek® SIV H3N2 (IDEXX, Westbrook, USA)

b) ELISA tests for zoonotic diseases caused by (licensed for blood serum AND meat juice):
   - *Salmonella* spp.: SALMOTYPE® Pig Screen (Labor Diagnostik Leipzig, Leipzig, Germany)
   - Trichinella spp.: PIGTYPE® Trichinella (Labor Diagnostik Leipzig, Leipzig, Germany)
   - *Yersinia enterocolitica:* PIGTYPE® YOPSCREEN (Labor Diagnostik Leipzig, Leipzig, Germany)
   - Toxoplasma gondii: PIGTYPE® Toxoplasma, Prototype prior to licensing (Labor Diagnostik Leipzig, Leipzig, Germany)

Collecting the blood and meat juice samples

In autumn 2009, at one slaughterhouse 291 selected pigs from six different herds of origin were individually marked by a consecutive tattoo number on the left foreleg after stunning the pigs at the point of bleeding, where simultaneously blood samples were taken. Later at the slaughter line, at the point of meat inspection, samples from the diaphragm pillar of the tattooed carcasses were collected. Both kinds of samples were strictly marked with the individual tattoo number so that every sample could be assigned unmistakeably to the correct pig and herd of origin.

Testing the samples

After freezing and thawing of the meat pieces for producing the meat juices and centrifugation of the blood samples for producing the serum all samples were tested with the selected set of ELISA-tests. Since only some of the tests are licensed for using meat juice as specimen additionally to blood serum (i. e. tests for the zoonotic agents), a decision on the dilution of the meat juice for this study had to be made. Taking into consideration the product information of the ELISA-tests licensed for blood serum AND meat juice, it became obvious that all those tests have more or less the same general rule for the dilution of serum and meat juice: meat juice is to be diluted ten times less than blood serum.

Assuming that any antibody concentration in blood serum is in general around 10 times higher than in meat juice (Nielsen et al., 1998; Molina et al., 2008), all tested meat juice samples were used with a 10-times lower dilution. The diluted 291 blood sera and the corresponding 291 meat juice samples were tested following exactly the test producers' instruction. The test results of all ELISA-tests, both with serum and with meat juice, were cumulated per pig herd of origin to identify serological herd profiles.

Considering the low prevalence of Trichinella spiralis (Jansen et al., 2008) and of Toxoplasma gondii [van Knapen, 1995; Lunden et al., 2002; Hill et al., 2006) in confined pig herds, additionally to the test-immanent positive controls at least one well per microtitre plate of these two tests was used for a confirmed Trichinella antibody positive or a confirmed Toxoplasma antibody positive serum or meat juice. This procedure was to assure that these two tests reliably would recognise positive samples as "positive". The positive Trichinella sera and meat juices were provided by the National Reference Laboratory for Parasitic Diseases at the Federal Institute for Risk Assessment, Berlin, Germany; the positive Toxoplasma control sera and meat juices were provided by the Institute for Parasitology of the University of Veterinary Medicine Hannover, Foundation, Germany.

Assessing the agreement between the results of serum and meat juice

Since the goal of this study is to create serological herd profiles only the cumulative dichotomous results based on the cut-off instructions of the test producers are of interest. Therefore, all primary OD% values were assigned to either "positive" or "negative". In the cases of *Mycoplasma hyopneumoniae, Yersinia enterocolitica,* Toxoplasma gondii, Trichinella spp. and Influenza A virus subtype H3N2, following the test instruction, the OD% values were assigned to "positive", "negative", or "doubtful". For critically assessing especially the capability of the tests to determine positive samples, the results "doubtful" were counted as "negative" results.

The sensitivity and specificity values of the meat juice test results compared to the corresponding blood serum test results were calculated.

The agreement of the dichotomous results (positive or negative) gained from serum and meat juice samples from the same pigs was assessed by calculating the Kappa values for agreement beyond chance, except of the test results for Trichinella and Toxoplasma. The analysed prevalence values are to low for meaningful Kappa values (Landis and Koch, 1977).

Retesting the same six herds for their serological profiles after one year

In autumn 2010, twelve months after the first sampling, random samples of meat juice from 160 selected carcasses from the same six herds were taken, to identify potential changes in the serological herd profiles of the study herds over time. The testing was carried out with the same seven test kits as the year before, but of course with newer test kit batches relying on the quality assurance data of the test producers that indicated that the inter-batch variations are negligible. The decision to use only meat juice samples for the comparison of the 2009 to the 2010 serological herd profiles was based on the sufficient degree of concordance of positive results in serum and meat juice also of those tests that had not yet been tested or licensed for meat juice (Tab. 1).

Results

Table 1 presents the proportion of positive results of the seven ELISA tests both in blood serum and meat juice for all 291 pigs/carcasses. In all seven test systems, the proportion of positive results in the paired sets of sera and the corresponding sets of meat juices is very similar. In total, the frequency of pigs that are *Yersinia enterocolotica* and *Mycoplasma hyopneumoniae* seropositive in both matrices is comparatively high (> 45 %) compared to the frequency of pigs that are seropositive against Toxoplasma gondii (< 3 %) and especially Trichinella spiralis (0 %). The frequency of pigs, which are seropositive against *Salmonella* spp. and the two subtypes of the Influenza A virus ranges between 7 % and 32 %.

The sensitivity values of the meat juice test results compared to the corresponding blood serum test results range between 55 % (H3N2) to 100 % (Trichinella, Toxoplasma, and Yersinia), whereas their specificity values do hardly vary, and are distinctly higher (91 % to 100 %).

The degree of agreement between positive results of the sera and the meat juices of exactly the same pigs is also shown in Table 1 as Kappa values: Following Trichinella and Toxoplasma (Kappa calculation not meaningful), the highest degree measured by the Kappa values show the serum and meat juice results of Yersinia (0.93) and Salmonella (0.87), and the lowest in the Influenza A subtype H1N1 (0.66) and subtype H3N2 (0.65).

Table 2 shows the positive test results of the meat juice samples per pig herd. The results of the herds A – G are listed in one row each. Additionally, the test results from 2009 and 2010 are coupled in the same row per herd. One the one hand this table structure is to demonstrate the "multi-serological" herd profiles (seven antibody frequencies per herd) and on the other the changes within the herd profiles over time.

In herds A and B, the serological profiles of 2009 and 2010 show quite little differences, whereas the herds C–G underwent more pronounced changes in their serological profiles. In contrast to the cumulative comparison of the serological results of all 291 pigs/carcasses (Salmonella: 12–

TABLE 1: *ELISA test results from blood serum and meat juice of 291 slaughter pigs in 2009 and the degree of agreement of the results.*

ELISA test for:	blood serum: proportion of positive samples (n/N)	meat juice: proportion of positive samples (n/N)	Sensitivity meat juice vs. serum	Specificity meat juice vs. serum	Kappa values
relevant for: food safety (zoonotic diseases)					
Salmonella spp.	13 % (38/291)	12 % (36/291)	87 %	99 %	0.87
Yersinia enterocolitica	69 % (202/291)	72 % (210/291)	100 %	91 %	0.93
Toxoplasma gondii*	2 % (6/291)	2 % (6/291)	100 %	100 %	n. c.
Trichinella spp.*	0 % (0/291)	0 % (0/291)	100 %	100 %	n. c.
relevant for: animal health (production diseases)					
Mycoplasma hyopneumoniae	51 % (149/291)	48 % (141/291)	91 %	96 %	0.86
Influenza A (H1N1)	32 % (93/291)	20 % (59/291)	61 %	99 %	0.66
Influenza A (H3N2)	11 % (31/291)	7 % (19/291)	55 %	99 %	0.65

*: all confirmed Trichinella and Toxoplasma positive control sera and meat juice samples were clearly identified as "positive"; n. c.: not calculated, prevalence values are too low for a meaningful Kappa value

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18 %; Yersinia: 52–72 %; Toxoplasma: 2–6 %; Mycoplasma: 36–48 %; H1N1: 20–21 %; H3N2: 6–7 %), the serological results of the individual serological parameter show, except for Trichinella, a remarkable inter-herd variation (e. g. Salmonella: 0–80 %; Yersinia: 0–100 %; Mycoplasma: 0–90 %).

Discussion

The presented results of a) the comparison of ELISA test results from blood sera and meat juice samples from the same pigs/carcasses, and b) the compilation of "multi-serological" herd profiles for the six herds are important sub-goals for the development of a systematic and on-going "multi-serological" monitoring for slaughter pig herds.

Comparability of meat juice and blood serum as specimens

The sensitivity values of the meat juice test results compared to the corresponding blood serum test results are the highest in those test systems, which are licensed for blood serum and meat juice (Trichinella, Toxoplasma, and Yersinia = 100 %, and Salmonella 87 %), whereas the tests that are not yet licensed for meat juice are less sensitive with meat juice (Mycoplasma hyopneumoniae = 91 %, H1N1 = 61 % and H3N2 = 55 %).

The calculated Kappa values for the agreement of the results of the serum and meat juice samples varied between 0.65 and 0.93, which points to a good to excellent agreement. This interpretation is based on the publications by Landis and Koch (1977), Wallenstein et al. (1981), and Hunt (1986). According to these publications, Kappa values between 0.4 and 0.75 represent a fair to good agreement, and 0.75 and above an excellent agreement. The good to excellent degree of agreement between the ELISA test results from meat juice and blood serum in this study points to the general usability of meat juice for assessing the infectious status of pig herds for the tested set of ELISA tests. Even with the low sensitivity of the meat juice tests for H1N1 and H3N2 these two tests can be regarded as usable for the meat juice multi-serology. This is due to a) the still relatively high Kappa values (> 0.6), and b) the fact that the test results are not intended to be used as a single animal diagnosis, but for a continuous serological herd profile assessment, in which the permanent retesting of pigs of the same herd at slaughter increases the identification rate of antibody-positive animals. The relatively lower sensitivity in combination with the high specificity of all meat juice test results compared to the serum test results (91 % to 100 %) show that there is room for adapting the sensitivity of the tests to the actual objective of the chosen serological monitoring by varying the dilution of meat juice, at least in those tests that are not yet licensed for meat juice. The proven general usability of meat juice has been already shown for *Salmonella* spp. (Nielsen et al., 1998; Steinbach et al., 2003; Hotes et al., 2010), for PRRSV (Molina et al., 2008) and for Classical Swine Fever (Kaden et al., 2009).

Using meat juice or blood samples collected at slaughter instead of collecting blood samples at herd level from live animals as specimen for ELISA tests will tremendously increase the acceptance for any on-going herd health monitoring of slaughter pig populations, since the sampling for such monitoring systems needs to be pragmatic, non-invasive, cost-effective and feasible without additional personnel. However, meat juice samples can be easier assigned to the corresponding herds of origin than slaughter plant blood samples, since at the point of collecting the meat pieces the carcasses are already individually marked and traceable. The advantages of meat juice over blood serum as specimen for the planned routinely run multi-serology system can be summarised as follows:

- taking muscle samples from carcasses saves any bleeding procedure at the farm that is stressful to people and animals. Collecting blood from pigs after stunning and bleeding at the slaughter line is possible, but the assignment of the samples to the herd of origin is more difficult than the assignment of meat pieces. They can be collected at the slaughter line, when every carcass has a clearly assignable identification (e. g. consecutive carcass numbers);
- in countries with existing serological salmonella monitoring programmes that are based on meat juice, the sampling is already implemented and in most cases well established – in those cases, no extra sampling system is needed, which means no extra personnel; and
- even in most countries without an established salmonella monitoring system, the collection of muscle samples from the diaphragm pillar is kind of trained due to the wide-spread sampling of muscle pieces from the diaphragm pillar for the Trichinella inspection based on microscopy.

All in all, the comparability of the serum and meat juice results allow for the decision to take blood or meat juice likewise, but in countries where there is already a meat juice based salmonella monitoring system, implementing the suggested multi-serological profiling using meat juice is much easier. In countries, where blood sampling at slaughter is already established, using blood samples for the multi-serology will be as easy as using meat juice samples.

The compilation of on-going multi-serological herd profiles

There is a longstanding practice to collect random blood samples of animals especially for the early detection of notifiable diseases in herds (Canon and Roe, 1982; Anonym, 2003). It has also become routine for diagnosing production diseases such as Enzootic Pneumonia (Nathues et al., 2006). But so far, these random samples are mostly taken at farm level. The idea of a multi-serology concept using meat juice for continuous monitoring programmes is new and the presented results of this study show that it is feasible and has the potential to become a meaningful tool for the implementation of the risk-based meat inspection.

There are four major areas, for which the proposed continuous meat juice multi-serology will be of usefulness:

1) providing the food operator and the veterinary authority with animal health information from the pig herds of origin that cannot be drawn from inspecting carcasses, with the so far not available information about the subclinical zoonotic infections (Salmonella, Yersinia, and potentially Mycobacteria and Hepatitis E Virus), and infestations (Trichinella and Toxoplasma) being the most important for food safety decisions – benchmarking or classifying the herds regarding the zoonotic status will allow for separating product lines;
2) providing the veterinary authority with additional data on the absence (or early recognition of the occurrence)

of notifiable diseases without the need for the government to implement a separate state system – these continuously generated data are not to replace well established early warning systems, but they will add to the assurance that a country is free from porcine epidemics that can be surveyed by serology;

3) providing the pig producer and his/her veterinary practitioner with information about the infectious status of the pig herd, which enables both to make more informed decisions in terms of the source of the animals, the vaccination strategy, and improving the health-related management measures – due to the continuous updating of the serological herd profile, any change over time (to the worse or the better) can be recognised;
4) providing the research community with new data that are opportunities for scientific analyses such as to look into risk factors for e.g. the varying intra-herd prevalence of *Yersinia enterocolitica* and Toxoplasma gondii.

The created meat juice multi-serological herd profiles in this study prove that pig herds can be classified in terms of the frequency of antibodies against various pathogens, with the possibility to look into zoonotic, notifiable and production diseases. If e. g. 60 animals per herd and year are tested, intra-herd frequencies above 5 % of antibody-positive animals can be identified (Blaha and Koefer, 2009). The continuously updated multi-serological herd profiles provide then the opportunity for introducing benchmarking systems. Such benchmarking will remarkably increase the informative value of the food chain information in the framework of the risk-based meat inspection and for targeted animal health improvements in pig herds.

The repeated testing of pigs of the same herd over time will identify changes in the infectious status for each tested pathogen, which will initiate targeted investigations at herd level and allow for drawing conclusions on reasons for the change and, thus, the efficacy or inefficacy of intervention measures. This means that the results of the suggested multi-serological monitoring should not be over-interpreted in terms of ad-hoc conclusions, but rather lead to targeted analyses at the farm in question by more specific veterinary diagnostics.

The increase of e. g. the salmonella seroprevalence seen in Herd C (Tab. 2) can be due to a variety of reasons such as an infected new animal source, a contamination of feed or water, deficiencies in the cleaning and disinfection protocol, which are to be identified by a targeted analysis of the risk factors at the farm. In the case of the steep increase of the H3N2 seroprevalence in Herd C (Tab. 2), will trigger the re-thinking of the vaccination strategy.

As for the initiation of scientific studies by the multi-serology, the reported results of this study have e. g. not only revealed an unexpected varying Yersinia intra-herd prevalence from 0 % to 100 % (Tab. 2), but they also allow for epidemiological investigations into herd factors for a high or a low Yersinia prevalence at herd level.

Apart from these opportunities, the major advantage of the suggested "meat juice multi-serological" approach is that this kind of multi-diagnostic monitoring addresses three

TABLE 2: *Comparison of the proportion of positive meat juices per herd in 2009 and 2010.*

Herd	Year	*Salmonella* (n/N) [0–80 %]	*Yersinia* (n/N) [0–100 %]	*Toxopl.* (n/N) [0–20 %]	*Trichinella* (n/N) [0 %]	*M. hyo* (n/N) [0–90 %]	SIV H1N1 (n/N) [0–37 %]	SIV H3N2 (n/N) [0–90 %]
A	2009	11 % (12/108)	69 % (75/108)	3 % (3/108)	0 % (0/108)	45 % (49/108)	26 % (29/108)	10 % (11/108)
	2010	10 % (8/80)	61 % (49/80)	9 % (7/80)	0 % (0/80)	45 % (36/80)	24 % (19/80)	0 % (0/80)
B	2009	6 % (2/31)	58 % (18/31)	3 % (1/31)	0 % (0/31)	39 % (12/31)	26 % (8/31)	3 % (1/31)
	2010	0 % (0/10)	100 % (10/10)	0 % (0/10)	0 % (0/10)	30 % (3/10)	30 % (3/10)	0 % (0/10)
C	2009	10 % (2/20)	20 % (4/20)	10 % (2/20)	0 % (0/20)	90 % (18/20)	0 % (0/20)	0 % (0/20)
	2010	80 % (8/10)	0 % (0/10)	20 % (2/10)	0 % (0/10)	60 % (6/10)	10 % (1/10)	90 % (9/10)
D	2009	0 % (0/28)	86 % (24/28)	0 % (0/28)	0 % (0/28)	32 % (9/28)	25 % (7/28)	25 % (7/28)
	2010	5 % (1/20)	35 % (7/20)	0 % (0/20)	0 % (0/20)	0 % (0/20)	25 % (5/20)	5 % (1/20)
E	2009	14 % (9/63)	82 % (52/63)	0 % (0/63)	0 % (0/63)	51 % (32/63)	0 % (0/63)	0 % (0/63)
	2010	5 % (1/20)	25 % (5/20)	0 % (0/20)	0 % (0/20)	0 % (0/20)	10 % (2/20)	0 % (0/20)
F	2009	27 % (11/41)	90 % (37/41)	0 % (0/41)	0 % (0/41)	51 % (21/41)	37 % (15/41)	0 % (0/41)
	2010	50 % (10/20)	60 % (12/20)	5 % (1/20)	0 % (0/20)	60 % (12/20)	20 % (4/20)	0 % (0/20)
Total	**2009**	**12 % (36/291)**	**72 % (210/291)**	**2 % (6/291)**	**0 % (0/291)**	**48 % (141/291)**	**20 % (59/291)**	**7 % (19/291)**
	2010	**18 % (28/160)**	**52 % (83/160)**	**6 % (10/160)**	**0 % (0/160)**	**36 % (57/160)**	**21 % (34/160)**	**6 % (10/160)**

groups of stakeholders: the food operators (food safety), the veterinary authorities (food safety and notifiable disease), and the pig producers (production diseases). Offering all three groups continuous information that serves their specific interests will provide the opportunity to share the costs of such monitoring systems. Such public-private partnership arrangements will improve the food safety, the surveillance of notifiable diseases, and will help the pig producers to maintain their competitiveness (Blaha and Koefer, 2009).

The current research at the Field Station for Epidemiology of the University of Veterinary Medicine Hannover, Germany focuses on: a) the validation of using meat juice for further pathogens such as the Classical Swine Fever Virus (CSFV), the Porcines Herpesvirus 1 (PHV1), *Mycobacterium avium,* the Hepatitis E Virus (HEV), the PRRS Virus and *Actinobacillus pleuropneumoniae,* and b) the miniaturizing of serological tests via the microarray or bead-based technology for simultaneously testing the selected set of pathogens that are to be included in variable multi-serological monitoring programmes.

As for financing a meat-juice serology monitoring as described, it needs to be highlighted that a) any monitoring system that is built on the principle "sample once and test manifold" means that every added test increases the cost-benefit ratio remarkably, and b) especially the proposal to combine three areas of interest (food safety, animal health and surveillance of notifiable diseases) provide the opportunity to share the costs of the suggested multi-serology by three: the food operator, the pig producer and the veterinary authority. The high potential of providing useful information for several important areas of the food chain that are increasingly debated publicly and the described cost efficacy especially due to the possible cost sharing should reduce the reluctance of implementing the concept.

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