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The capacities of laboratories in Serbia for testing meat quality and safety

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A b s t r a c t: Thanks to its content, and primarily due to that of nutrient materials, meat can be found nearly daily in the diet of humans. Predictions indicate that the upcoming period expects to see a rise in both the production and consumption of meat worldwide. However, in addition to satisfying the needs of the consumers in terms of the quantity of meat, it is also important to satisfy their needs when it comes to quality, meat safety, and the reliability of the information provided. Furthermore, it is in the interest of the consumer that the testing of the meat be carried out in accredited laboratories in line with SRPS ISO/IEC 17025:2017. Bearing in mind the great number of parameters which are tested with the aim of determining quality, safety, and meat authenticity, it is the goal of this paper to analyse the capacities of the accredited laboratories for carrying out such tests. By applying the methodology (the Accreditation Body of Serbia's website was searched), it was determined that 58 laboratories in Serbia have at least one, but more commonly multiple accredited methods which each laboratory can use in order to examine several of the parameters for safety and/or meat quality. It was determined that the capacities of the laboratories, in both the private and the public sectors, for testing the parameters of meat quality and safety in Serbia were sufficient, particularly for the parameters of meat safety which, according to research, is the area which worries consumers the most. What should definitely be a joint task for testing laboratories and the state competent authorities is the development of methods through which meat fraud could be detected.

Keywords: *meat, safety, quality, fraud, laboratory testing, accreditation.*

Introduction

Thanks to its nutritional content, meat is one of the most valuable foods in existence and is present in the diet of most people on a near-daily basis (*Baltic & Boskovic*, 2015). Animal-based proteins are also known as complete proteins, given that they contain all essential amino acids (*Zhubi-Bakija et al.,* 2021). In addition to essential amino acids, meat is a significant source of micronutrients, particularly Fe, Zn, Se, Cu, Mg, Co, Pb, Cr, and Ni. Furthermore, it is important to highlight that these elements are far more efficiently absorbed compared with those of plant-based origin. Meat, alongside other animal-based food, is an important source of vitamin B12, which vegetarians and vegans tend to have a deficit of (*Stanisic et al.,* 2018).

Bearing in mind the importance of animal-based protein for the human diet, the need for animal-based protein is reflected in the ever-growing production of meat worldwide. Despite the fall of meat production globally as a consequence of 2019's African Swine Fever outbreak, the predictions for production and consumption of meat look different for the upcoming period. According to data (*OECD/FAO,* 2020), it is believed that the consumption of meat will increase by 12% by the year 2029. The prediction is that nearly the entirety of this rise will be the consequence of consuming poultry meat, as its price is lower, making this type of meat more accessible to citizens of developing nations.

It is believed that the rise in meat consumption will become typical for developing countries, which are known for their high population levels and growth rates. The expectation is particularly high for Africa and Asia where, despite low per-capita incomes, meat consumption will be greater due to the liberalization of the market, which leads to lower costs of meat. Developed countries are expected to see a fall in the consumption of meat per person in comparison with the previous decade (*OECD/FAO,* 2020). The reason for this is that the developed nation consumer has a choice when it comes to food, prefers options when it comes to quality, and takes into account factors such as nutrition, well-being, and health, thereby enabling them to be choosy and place high demands (*Sarcevic et al.,* 2011). Simultaneously, the eating habits of those individuals living

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in countries with high incomes are changing and, rather than purchasing fresh produce and preparing it in their own homes, they opt to dine at restaurants with more frequency. Furthermore, the number of households consisting of the elderly or singles is on the rise, for whom eating outside the home has become the norm (*OECD/FAO,* 2020).

According to the *Statistical Office of the Republic of Serbia* (2020a), the sum of consumed quantities of meat per household in Serbia amounted to 123.3 kg in 2019. The breakdown of meat consumption according to type is as follows: beef (fresh and frozen) 16.8 kg/household, pork (fresh and frozen) 49.6 kg/household, poultry and other (fresh and frozen) 50.2 kg/household, and other kinds of meat (fresh and frozen) 6.7 kg/household. Statistics on the amount of meat produced in 2019 show total meat amounted to 548,000 tons, wherein the production of beef amounted to 71,000 t, pork 298,000 t, mutton 34,000 t, poultry 114,000 t, and edible offal 31,000 t (*Statistical Office of the Republic of Serbia*, 2020b). This reflects a mild growth in the total production of meat compared with the previous two years.

It is a recognized fact that the modern-day consumer is far pickier when it comes to meat quality and safety and product labelling, as well as the producers being determined to implement standards in food production, etc. (*Sarcevic et al.*, 2011). Consequently, in addition to handling the growth in production, the meat industry is also responsible for satisfying all the needs of consumers in terms of availability of their desired amounts. Although the importance of meat in the human diet cannot be neglected, given its favourable composition of nutrient-rich materials, primarily protein, vitamins, and minerals, but also desired sensory characteristics, what cannot be ignored is the truth that meat has the potential to be a significant source of biological, chemical, and physical hazards. Consuming unsafe meat can lead to meat-borne illnesses, namely, infection, toxification, or intoxication (*Kilibarda,* 2019).

Meat production assumes the raising of the animal, the transport of the animal, slaughter, processing the carcass, freezing, packing, and storing. It also includes the distribution, selling, preparation, and serving of the meat when consumed in individual households (*Das et al.,* 2019). It is important to highlight that meat can become contaminated by any number of hazardous substances at every given phase in its production chain. Chemical hazards, such as the residues of veterinary medications, which can sometimes be found in the meat of the animal at slaughter during primary production are, above all, the effect of unconscionable and inexpert usage of veterinary drugs. The presence of pesticides and heavy metals in meat and other edible parts of the animal is the consequence of the animal's exposure to those contaminants found in the environment in which they live (*Viegas et al.,* 2012; *Smith & Kim,* 2017). Potentially harmful pollutants in the environment and toxins as a result of human activity can also be found in the meat of animals, including inorganic elements such as As, Cd, Hg, Pb, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins, and others. Inadequate transportation of animals (unhygienic conditions or a large number of head per unit of transport area) is a significant risk for the presence of cross-contamination by bacterial pathogens. Furthermore, the inhumane treatment of animals prior to their slaughter, exposing them to stress, has an additional negative influence on the quality and safety of meat. The slaughter line has numerous points during which contamination by potentially pathogenic microorganisms is possible, and the causes of contamination are numerous (the workers' hands, the equipment, the carcasses themselves) (*Karabasil et al.,* 2008). During the final stage of the food chain, the quality and safety of meat is influenced by a great number of factors, including the packing, storing, transport, and sale, as well as the treatment of meat in the actual households. Meat is, given its physico-chemical characteristics and the content of nutrient materials, a substrate which favours the growth of microorganisms. As such, it is considered an easily perishable food, so maintaining the cold chain throughout the distribution of meat is imperative. Because of that, the cold chain must not be stopped, and it is particularly important to prevent the arrival of cross-contamination throughout this stage (*Das et al.,* 2019). As the main biological meat-borne hazards, *Buncic* (2015) lists pathogenic microorganisms, *Campylobacter, Salmonella*, *Yersinia*, verocytotoxigenic *Escherichia coli*, *Listeria monocytogenes*, *Trichinella*, *Toxoplasma gondii*, norovirus, hepatitis A virus, hepatitis E virus, and prions that cause transmissible spongiform encephalopathies (TSEs) in humans. The WHO estimates that *Salmonella* spp., *Campylobacter* spp., norovirus and hepatitis A virus are important, common foodborne hazards that lead to illness in humans, and are transmitted through food of animal origin (*WHO;* 2017). Eating food of animal origin was associated with most strong-evidence foodborne outbreaks (*EFSA & ECDC*, 2021). However, regardless of the fact that the data indicates that biological hazards most commonly lead to illnesses in humans, research on consumers in the European Union (*Sofos,* 2008; *Viegas et al.,* 2011) indicates that, when it comes to food-borne risks, what concerns consumers the most is their exposure to veterinary drug residues inside the meat (*Verbeke et al.,* 2007; *European Commission*; 2019; *Rembischevski & Caldas*, 2020). This would appear to be contradictory, given that the use of substances with hormonal action on animal farms is prohibited within EU borders by Council Directives No. 96/22/EC (*EC,* 1996) and 2003/74/EC *(EC,* 2003a). Also, according to Regulation (EC) No. 1831/2003 (*EC*, 2003b), the use of antibiotic growth promoting substances as additives for use in animal nutrition is forbidden (*Andree et al.,* 2011). Despite that, the latest research on Danish consumers indicates that up to two thirds of consumers are willing to pay higher prices for pork if they were able to know that the pigs had been raised in a manner which reduces the need for antibiotic usage over the course of their lifetime (*Denver et al.,* 2021). A reason listed as to why veterinary drug residues in meat are perceived by consumers as presenting the highest risk is because these hazards are invisible to the consumers, having long-term effects and serious health consequences (*Ha et al.,* 2019). In general, chemical hazards to the consumers are something unknown and unnatural, and as such, are assumed to be a greater risk. Consumers are much more familiar with and have far more knowledge about biological hazards, which is a likely consequence of consuming unsafe food containing biological hazards, which cause momentary and acute impacts. Furthermore, the consumers of biological hazards experience such events as something which they can influence and control, unlike chemical hazards, over which they have no possibility of controlling (*Kher et al.,* 2013).

Moreover, what has been leading to rising doubt and concern among the consumer today is, in fact, food fraud (*Das et al.,* 2019). Food authenticity and meat authenticity pose questions of the highest concern in modern-day society (*Premanandh*, 2013). The demand for meat from specific geographic regions continues to grow, as does that for meat products produced in a traditional manner, which consumers believe to be high-quality food, and which adds to its value (*Montowska & Pospiech*, 2012). In addition, the Muslim community has demonstrated an ever-growing interest in confirming the status of Halal meat which they consume in order to ensure that it does not contain additions that are not in line with their religion and traditions. All this justifies the global need for the consumer worldwide to have access to information, which is accessible, clear, correct, and reliable. As such, several peer-reviewed papers were published recently which dealt with this very question (*Ali et al.,* 2012; *Farouk,* 2013; *Nakyinsige et al.,* 2012). When it comes to meat fraud, these economically-motivated and illegal actions can be divided into three categories: 1) concealing the origin of the meat and the animal's diet (incorrect, or rather, false information concerning its origins, for example, when it comes to meat with geographic indication); 2) replacing the ingredients of one type of meat with those of a different type of animal; and 3) adding non-meat components, such as water or additives, into the meat (*Ballin,* 2010). For these reasons, it is the duty of the government to ensure all necessary resources (both material and human) that will allow for the constant development of methodologies with which it will ensure the establishment of potentially illegal activities whose ultimate goal is to economic benefit, yet which lead to consumer confusion and harm the quality of the meat (*Spink & Moier,* 2011; *Sentandreu & Sentandreu* 2014).

The issue of food safety and quality, as well as meat fraud, is a complex concept which depends upon many factors, given the greater number of hazards and paths leading to meat contamination. It also depends on illegal practices through which meat can end up adulterated, or which could lower its quality (*Sofos,* 2008; *Viegas et al.,* 2012). For these reasons, meat, and the food which we consume in general, are tested in laboratories more so than ever before. They are tested through the application of various methods and by using high-performance equipment, thereby determining both the quality and the safety of meat with a high degree of reliability. Due to the globalization of the food market, the issue of food safety requires a global approach. This is why it is of utmost importance for food inspection to be carried out in a way that is internationally recognized by laboratories, with the aim of establishing the presence of hazards within the food, as well as confirming additional quality, regardless of whether it be through official or internal controls.

According to the law on food safety (*Serbia*, 2009, *Serbia*, 2019), it is a requirement for laboratories that perform laboratory testing in the process of official controls in the fields of food safety and fodder safety to be accredited in line with the demands of the SRPS ISO/IEC 17025:2017 standard (*SRPS*, 2017) – General requirements for the competence of testing and calibration laboratories. The process of accreditation, which is an independent and impartial grade of competency of the body that carries out the tasks of testing, is the best path towards determining a laboratory's performance. Receiving a certificate for accreditation of the laboratory determines its superior positioning in the market, and allows for international recognition for technical competency, that is, internationally recognized results for the testing which it carries out. This way, by obtaining a certification of accreditation, the laboratory is able to provide its clients with objective proof that the research it carries out is done so competently, and that the results of the tests are reliable, valid, and in line with the prescribed requirements, specifications, standards, and rules (*Rajković et al.,* 2019). This also demonstrates that its work has been verified by an independent institution, that is, within Serbia, the Accreditation Body of Serbia. The accreditation of a laboratory for testing food supports a global approach in ensuring the safety and quality of food, given that the signing of The European co-operation for Accreditation Multilateral Agreement (EA MLA) (an agreement of international recognition of accreditation) recognizes the equivalence and reliability of reports published by foreign bodies for grading compatibility throughout Europe. The Accreditation Body of Serbia has been a signatory to this agreement since 2012.

Given the large number of parameters which must be examined in the process of grading meat in terms of quality, safety, and authenticity, the aim of this study was to analyse the capacities of laboratories to carry out such tests. Because of the very global approach to this problem, only laboratories with accredited methods testing parameters of interest were taken into consideration for this analysis in order to gauge their current capacities, competitiveness, and the international recognition of testing laboratories in Serbia.

Materials and methods

With the aim of gathering data on accredited laboratories in Serbia with the capacity to examine the parameters indicating quality, safety, and meat fraud, the Accreditation Body of Serbia's website was searched in the period between May 2nd, 2021 to May 9th, 2021. The key word "meat" was used during the web searches in order to discover, from among all the testing laboratories accredited by SRPS ISO/IEC 17025:2017 (*SRPS*, 2017), those with meat as a subject of inspection. However, upon additional inspection, it was determined that the site's search function was created in a way as to take into account smaller content descriptions of accredited laboratories, which often included food as a wider concept, but not specifically meat, meaning a new approach to the search had to be taken on. For more reliable searches and, as such, results, the key word used was "food". The selection of the laboratory was then conducted by insight and analysis, providing a valid range of selected, accredited laboratories. For the purposes of further analysis, only those laboratories with the goal of testing through the application of various methods and techniques encompassing meat were included. After that, a database was created using Microsoft Office Excel 365 in which the extracted parameters were analysed. Descriptive statistics, percentages, and graphic representation of the results were also processed using Microsoft Office Excel 365. The safety and meat quality parameters, in relation to the research techniques, were sorted after analysis in the following way. The meat safety parameters singled out pathogenic microorganisms, the presence of which is tested by applying the standard methods or the polymerase chain reaction (PCR) method. The presence of the *Trichinella* parasite in pork is determined using the method of artificial digestion. Tests for the presence of metals, metalloids, and other chemical components, pesticide residues, veterinary drug residues (confirmative and screening methods), PCBs, PAHs, and radionuclides follow different procedures. As parameters for the basis upon which the quality of meat is graded more narrowly, physico-chemical and sensory testing capacities were extracted. The parameter for uncovering meat fraud included methods for determining the presence of species-specific animal-origin DNA (using the PCR method or an ELISA test).

Results and Discussion

By applying the methodology, it was determined that 58 laboratories in Serbia have at least one, but more commonly multiple accredited methods which each laboratory can use in order to examine several of the parameters for safety and/or meat quality. The geographical distribution of the laboratories is indicated in Figure 1, whereby noticeably, an equal number of laboratories (n=18; 31%) can be found in Belgrade and in the Autonomous Province of Vojvodina. Out of the total number of laboratories, 38% (n=22) were distributed throughout the rest of the territory of Serbia. Privately owned laboratories constituted only 22% of the total laboratories (n=13), while 78% of the laboratories were state-owned, with the structure visible in Figure 2. The greatest percentage of laboratories for testing several of the meat hygiene parameters were represented precisely by the Public Health Institute (hereinafter, public health laboratory), which carries out tasks in the fields of health activities, and which the Government founded (47%, n=21). Next up were the laboratories within the research institutes or scientific or educational institutions, namely faculties (22%, n=10) (hereinafter scientific laboratories). The veterinary institute, which carries out these activities in the field of veterinary sciences (hereinafter veterinary laboratories), made up 22% (n=10) of the total number of laboratories in the government sector, while the smallest percentage was found within state property (9%, n=4) (hereinafter public laboratories).

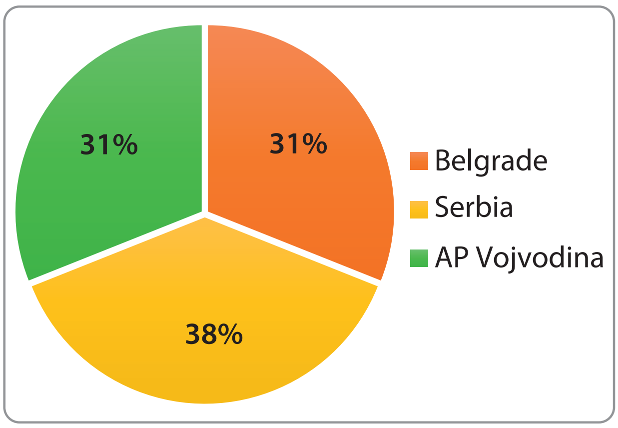

Figure 1. Geographic distribution of the laboratories in Serbia

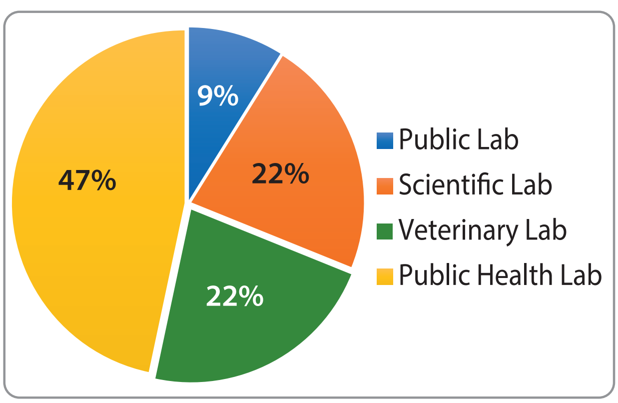

Figure 2. Structure of the state-owned laboratories

The geographic distribution of these laboratories according to sector (private, public) can be viewed in Figure 3. Noticeably, over half of the privately-owned laboratories were located in Belgrade – 7 out of a total of 13 – and the Public Health Institutes are found distributed around all of Serbia. An interesting fact is that the accredited laboratories found within the frameworks of institutes and/or faculties were found exclusively in Belgrade (n=6) and Vojvodina (n=4). This is unusual, given that the university centres of Serbia include the cities of Niš and Kragujevac. The conclusion is drawn that it is precisely the differences in development and the per capita income between Belgrade, Vojvodina, and the rest of Serbia that reflect the weaker amount of investment into science and technologies in Niš and Kragujevac. The territorial distribution of all ten veterinary institutes is in line with the epizootiology territories of Serbia.

Given the parameters which were examined with the aim of grading meat quality and safety, and which can be found stated in the assigned space concerning the accreditation of laboratories, the capacities of accredited laboratories for this type of research compliance were analysed (Figure 4).

It can generally be stated that the majority (88%) of the analysed laboratories had the capacity to test for the presence of microorganisms in meat. The microbiological parameters of meat safety were generally researched using standard methods, while the average number of accredited methods was 12, bearing in mind that one of those laboratories (a scientific laboratory) had 31 accredited microbiological methods. A smaller number of laboratories had the capacity to validate the number/presence of pathogenic bacteria (such as *Salmonella* spp.) in meat through rapid tests. When it comes to researching the microbiological parameters, it is interesting to mention that all private, veterinary, and public health laboratories had the capacity to examine these meat safety parameters using accredited methods. The situation was somewhat different in the scientific laboratories, given that (only) half of these laboratories have opted for accreditation of their microbiological methods, while some of them only performed one type of testing, which was most often testing for the presence of radionuclides through gamma spectrometry. Based on the analysed data, the significant laboratory capacities for testing the presence of biological hazards in food using standard microbiological methods can be explained by the fact that investment into microbiological research does not require extensive financial resources, nor long-term absence of the staff due to training or specialization. Such is not the case with methods in the fields of researching chemical hazards, such as veterinary drug residues, pesticides, the presence of heavy metals and similar, which require high-performance equipment and highly trained staff.

The situation was somewhat different when it comes to testing for the presence of pathogenic microorganisms by applying PCR methodology, which only five laboratories (9%) had accredited; of those, three were private, one was veterinary, and one was a public health laboratory. This is to be expected, given that the legal regulation itself prescribes standard microbiological methods for testing for the presence of biological hazards. The equipment, the training of the staff, and the activities associated with the fields of ensuring trust in the quality of the testing require significant material investment, which is why laboratories more rarely opt for this type of testing.

Testing for the presence of the *Trichinella spiralis* parasite, which induces human trichinellosis by the consumption of undercooked domestic pork and meat products (especially sausages), and today, more often by the consumption of raw or undercooked wild and home-raised game meats (*Diaz et al.,* 2020), is carried out by the reference method of artificial digestion. Out of the total number of analysed laboratories, 24% of laboratories, of which were nine out of the ten veterinary, three scientific, and two private laboratories, had accredited this method of testing. The presence of this method of testing compared with the laboratory structure is to be expected, given that this method should be carried out by graduate veterinarians who are employed in veterinary organizations.

When it comes to meat quality parameters, which are determined by testing the physico-chemical properties of meat, it was established that, alongside microbiological testing, this type of testing is the one most commonly found in accredited laboratories, that is, these tests were carried out by over half of the analysed laboratories (53%). The physico-chemical parameter tests were accredited in 77% (n=10) of private laboratories, 62% (n=13) of public health laboratories, and 50% (n=5) of scientific laboratories, while only

Figure 3. Geographic distribution of laboratories according to sector (private, public)

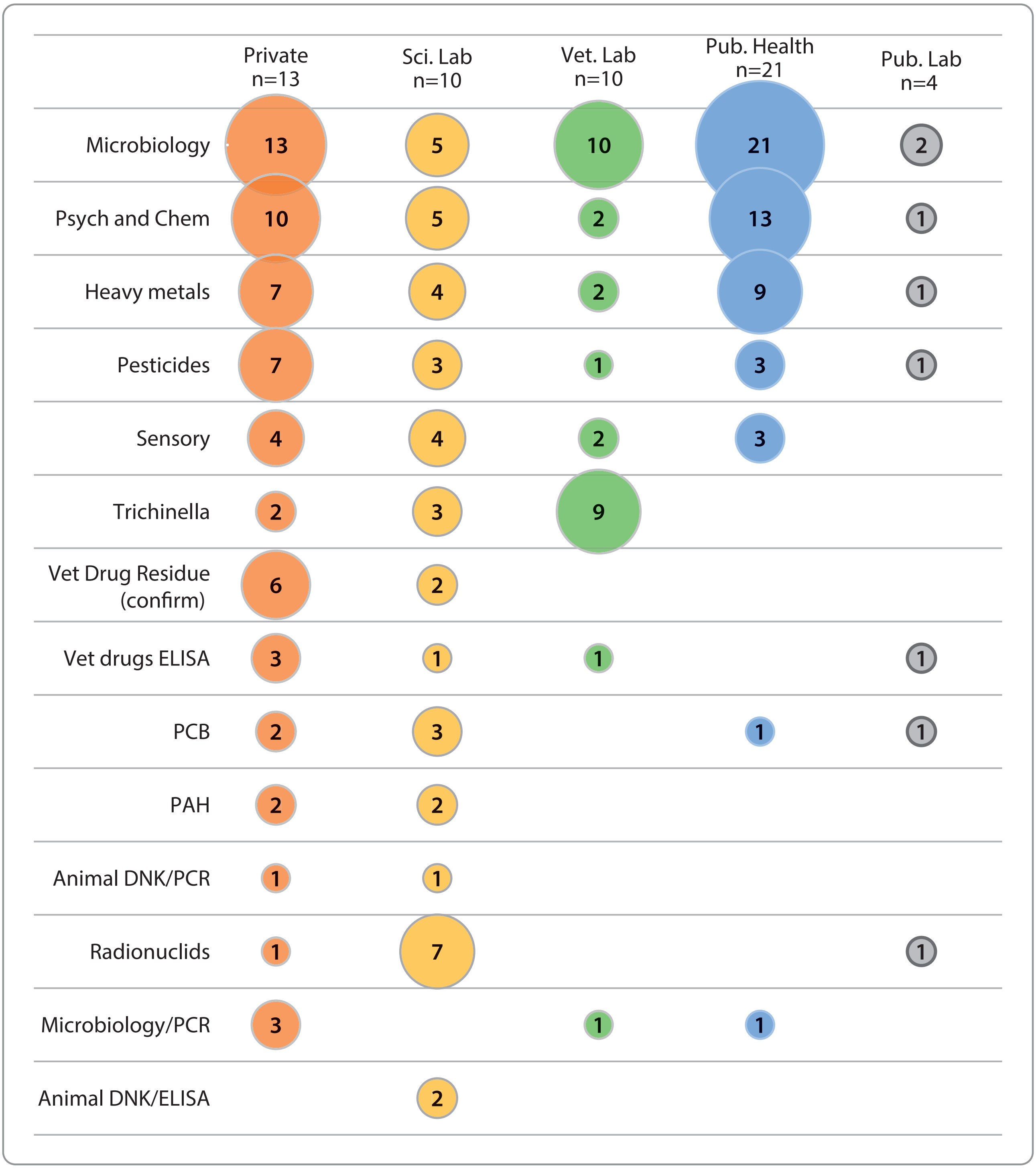

Figure 4. The capacities of accredited laboratories in Serbia

two (20%) veterinary laboratories had this capacity, as did two out of four public laboratories. The sensory testing is interesting in that it determines the parameters of meat quality, which is an area not covered by our own laboratories. Out of 58 laboratories, only 22% (n=13) carried out sensory testing using accredited methods. Sensory testing does not require any specific equipment nor great investment. However, the belief may be that performing sensory testing requires a well-trained staff in order for the subjectivity of this testing to be reduced to a minimum. Likely, it is a lack of trained human resources that leads to laboratories not opting for accreditation of this method. It is also very important to mention that, when it comes to parameters of quality, only one private laboratory in Serbia has the capacity to apply high performance liquid chromatography (HPLC) technique to determine amino acid compositions of meat, as well as the presence of vitamins B1, B2, B6, A, C, and D using accredited methods. Moreover, only one public health laboratory has the capacity to determine the presence of vitamins B1, B2, and B6.

Heavy metals, such as Pb, Fe, Cd, Hg, Cr, Cu, As, and Ni, are rooted in natural, but also artificial sources, the latter of which is the direct consequence of human activity, that is, industrial production, which ends up in landfills and water sources. By way of food and water, animals consume these metals which then accumulate in their tissues and organs, and in this way, the hazards enter the food chain. If consumers are exposed to unsuitably large amounts of these chemical hazards through meat and edible animal parts, this could lead to serious health consequences (*Andree et al.,* 2011; *Mahmutovic et al.,* 2018). This is why it is of exceptional importance that laboratory capacities exist for the purposes of testing for the presence of such hazards in food. This research determined that the presence can be determined of metals and metalloids and other chemical elements of interest in meat by accredited methods in 40% of all analysed laboratories, those being: 54% (n=7) of private laboratories, 40% (n=4) of scientific laboratories, 20% (n=2) of veterinary laboratories, 43 % (n=9) public health laboratories, and one public laboratory. These food safety parameters are overwhelmingly tested by using the atomic absorption spectroscopy (AAS) technique. However, the inductively coupled plasma-optical emission spectroscopy (ICP-OES) technique for determining chemical elements was carried out by six laboratories, of which three were public health laboratories, two were private laboratories, and one was a public laboratory. Furthermore, five laboratories had the capacity to use the inductively coupled plasma mass spectrometry (ICP-MS) testing technique to determine the presence of the elements of interest in meat (three private laboratories, and two scientific laboratories). It is very important to emphasize that, through the application of both techniques − ICP-OES and ICP-MS − a more sensitive analysis of a great number of chemical elements can be carried out simultaneously, up to the milligram and nanogram levels. The conclusion can be drawn that Serbia has significant laboratory capacities for testing for the presence of chemical elements in meat and edible parts, given that a full half of the laboratories have the capacity to carry out more sensitive techniques, such as ICP-OES and ICP-MS.

Veterinary drugs are used as therapeutic measures for controlling various animal diseases, for prophylactic measures, and for controlling parasite infections (*Das et al.,* 2019). When they are applied recklessly and inexpertly, the remains of veterinary drugs can enter the food chain, after which consumers can be exposed to these chemical hazards which, as mentioned previously, is of the most critical importance when it comes to the consumer. The residues of veterinary drugs in meat are determined through the application of the HPLC technique, which is a confirmative method when compared with the screening methods which are carried out by, for example, ELISA techniques (*Andree et al.,* 2011). By use of confirmative methods, the presence of veterinary drug residues was able to be established in seven private and two public laboratories (14% of the total accredited laboratories). The laboratories usually have the capacity to test for the presence of residues of those drugs which are most frequently used in practice, which are the residues of sulphonamides and tetracycline. However, one of the scientific laboratories has the capacity to apply liquid chromatography–mass spectrometry (LC-MS), through which it can examine for a great number of veterinary drug residues: anti-inflammatory drugs, steroids, thyrostatics, anthelmintic, coccidiostats, natamycin, metabolites of a quinoxaline, macrocyclic lactones, bacitracin, chloramphenicol, thiamphenicol, fluorphenicol, quinolone, metabolites of nitrofuran, tetracycline, nitroimidazole, β-lactam antibiotic, sulphonamide, and aminoglycoside. One private laboratory had the capacity to determine the presence of residues of coccidiostats, natamycin sulphonamides, and tetracyclines and chloramphenicol. When it comes to applying the screening methods, such as the ELISA technique, the capacity to test for veterinary drug residues was found in six laboratories (10%), while one of them, a scientific laboratory, had the capacity to test for a great number of veterinary drug residues; the other laboratories generally tested for the presence of antimicrobial drug residues.

The capacity to test for pesticide residues in meat by application of the gas chromatography method and/or chromatography with various detectors was found in 14 laboratories (26%), of which seven were private, two were scientific, three were public health laboratories, and one was a veterinary, or rather, public laboratory. The laboratories had the capacity to determine the presence of levels of 10 pa, and over 40 types of pesticides in meat. It is clear that the number and types of pesticides which can be determined by the accredited methods are, overwhelmingly, dictated by the market, but it is important to emphasize that laboratories in Serbia have all the capacities necessary to, in accordance with the needs and demands of the consumers, test an even greater number of pesticides in meat. In that sense, laboratories could be reviewed for receiving accreditation for a flexible scope that would enable them the assigned responsibility for managing the extent of the accreditation and the possibility of carrying out changes in the acquired scope of the accreditation, without previously receiving appraisement from the Accreditation Body of Serbia.

When discussing the presence of other environmental contaminants, the presence of PCBs was tested through the use of gas chromatography in seven laboratories (12%), three of which were scientific, one was public, two were private, and one was a public health laboratory. The presence of PAHs in meat was tested through the application of the gas and/or liquid chromatography methods using various detectors by only 7% of the total number of analysed laboratories (two private and two scientific).

Determining the presence of radionuclides by testing with gamma spectrometry was possible in nine laboratories (16%), of which one was private, one was public, and seven were scientific laboratories. Of these seven scientific laboratories, four of them performed only gamma spectrometry testing of meat, that is, they have only one accredited method for testing the parameters, in this case, for meat safety. This situation is truly understandable, given that this is a very specific type of test which requires, primarily, particular infrastructure solutions.

As far as methods for determining meat adulteration go, as mentioned above, some laboratories determined the presence of chemical elements by using the ICP-MS technique. However, the application of this technique is made possible through isotopic analysis. The measurement of stable isotope ratios and trace elements is the method with which it is possible to determine meat origins and the animal's feeding regime, and to confirm or refute information concerning its origin, that is, to detect potential meat fraud. The conclusion can be drawn that these laboratories, although not located within the assigned scope of accreditation, could have the capacity and opportunity to confirm meat origin or uncover meat fraud. Among the methods that use that non-targeted approaches when uncovering meat fraud was nuclear magnetic resonance (NMR) to detect the fraudulent addition of water, so this technique analyses water distribution in fresh meat in relation to meat quality parameters, such as water holding capacity, tenderness, and juiciness (*Bertram & Andersen*, 2007; *Pearce et al.,* 2011). Another method used was histology and image analysis, based on light or electron microscopy in combination with digital analysis of images. Metabolites in meat have been analysed by the use of either liquid (LC) or gas (GC) chromatography coupled to different detectors. When it comes to methods which have targeted approaches with the aim of uncovering meat fraud, the ELISA technique is likely the most commonly used one for determining the presence of animal-origin DNA in meat (*Asensio et al.*, 2008). In spite of its many advantages, this technique is not highly specific, and often produces false positive results due to cross-reactions between the antibodies used. Serbia has two scientific laboratories which have accredited methods for determining the presence of animal-origin DNA in meat using the ELISA technique. Methods based on DNA analysis, and particularly those based on PCR, are very sensitive and reliable, and hence have a high level of sensitivity, reflected in the fact that it is possible to uncover as little as 0.1% of added meat protein from different kinds of animal *(Natonek-Wisniewska et al.,* 2013). However, this high level of sensitivity, or rather, ability to detect very small amounts of fraudulent material, is not needed to determine meat fraud, given that fraud takes place in order to increase economic benefit, which is why prohibited ingredients are added at amounts of greater than 10%. Still, this specific case of meat fraud could be of great importance for the Muslim population, for whom the presence of any amount of pork (even 0.1%) would render the meat unacceptable for this community (*Mohamad et al.,* 2013; *Sentandreu & Sentandreu,* 2014). The detection of animal protein by use of PCR was available through only two laboratories, one scientific, and one private.

Finally, it is important to highlight why the goal of this paper was to provide a broad picture and analysis of the capacities of accredited laboratories for the purposes of testing the parameters of meat safety and quality, as well as the option of uncovering meat fraud. Reviewing detailed analyses of the appraised scope of specific laboratories goes beyond this study. What can generally be said is that laboratories from the private sector, although constituting a smaller percentage (22%) of the laboratories analysed, had significant capacities and potential to test a large number of specific meat hygiene parameters. Roughly divided, half of the accredited scientific laboratories, and one of them in particular, had the potential to test a large number of parameters, while the other half has opted for just one type of testing, primarily using gamma spectrometry to establish the presence of radionuclides. As far as public health laboratories go, even though they are the most numerous of the laboratories studied, it is important to mention that their capacities for testing meat were often limited to microbiological testing, which is understandable given that the scope of their work is usually focused on testing water, dietary substances, and supplements. Veterinary laboratories stood out for carrying out practically all of their testing using the artificial digestion method for *Trichinella*, which is also to be expected, but only a small number of these laboratories had the capacity to test a greater number of parameters of meat hygiene.

Conclusion

Alongside demands for food to be safe and of high-quality, consumers today request ever more clear and reliable information about the food they consume. In order to ensure the safety and quality of meat, an honest market and the freedom of choice for each individual, it is the task of the government to guarantee that information concerning food found on the market be correct. This is why accredited laboratories with the capacity to test and confirm food quality and safety play a supporting role, as it is of exceptional importance today due to market liberalization and the increase in international trade and the global approach to food safety. The product of each laboratory is precisely its report on the results of the research, and the granted accreditation for the job of testing provides confirmation that those results are correct, reliable, and internationally recognized. This can, to a great extent, influence directly and indirectly the reputation and position of a country on the international market. Even so, it is important to keep in mind that the methods for testing are not perfect analytical tools, despite the high sensitivity, specificity, reliability and robustness, which is why various approaches to insuring safe, high-quality food must be applied, from the provider to the consumer. For these reasons, in the production of safe and high-quality food, the scientific laboratories and internal laboratories of the meat industry provide a significant contribution, as it is their business goal to be focused on competitiveness in the market and, as such, these types of tests are not accredited in accordance with the SRPS ISO/IEC 17025:2017 standard. In conclusion, the capacities of laboratories from both the public and the private sectors in Serbia for testing the parameters of meat quality and safety are sufficient. This is especially the case for testing for veterinary drug residues in meat which, according to research, are the chemical hazards of most concern to consumers. The capacity of one laboratory in particular stands out for that, in which it is possible through the use of accredited methods, to establish the presence of a significant number of various groups of veterinary drugs. What should definitely be a joint task for testing laboratories and the competent state authorities is the development of methods through which meat fraud could be detected.

Kapacitet laboratorija u Srbiji za ispitivanje bezbednosti i kvaliteta mesa

Nataša Kilibarda

A p s t r a k t: Zahvaljujući svom sastavu, a pre svega sadržaju hranljivih materija, meso je gotovo svakodnevno zastupljeno u ishrani ljudi. Prognoze su takve da se u narednom periodu očekuje kako porast proizvodnje, tako i porast potrošnje mesa na globalnom nivou. Međutim, pored potrebe da se zadovolje zahtevi potrošača u pogledu količine mesa, veoma je važno da se zadovolje zahtevi u pogledu kvaliteta, bezbednosti mesa i pouzdanosti pruženih informacija. Takođe, u interesu potrošača je da se ispitivanje mesa obavlja u laboratorijama akreditovanim u skladu sa SRPS ISO/IEC 17025:2017. Imajući u vidu veliki broj parametara se ispituju u cilju procene kvaliteta, bezbednosti i autentičnosti mesa, cilj ovog rada je da se analiziraju kapaciteti akreditovanih laboratorija za izvođenje tih ispitivanja. Analizom dostupnih informacija na zvaničnom sajtu Akreditacionog tela Srbije, utvrđeno je da 58 laboratorija u Srbiji ima najmanje jednu, ali najčešće više akreditovanih metoda kojima je u mogućnosti da ispita neke od parametara bezbednosti i/ili kvaliteta mesa. Zaključeno je da su kapaciteti laboratorija, i privatnog i državnog sektora, za ispitivanje parametara kvaliteta i bezbednosti mesa u Srbiji dovoljni, posebno za parametre bezbednosti, koje po istraživanjima, predstavljaju hemijske opasnosti koje potrošače najviše i zabrinjavaju. Ono što definitivno treba da bude zajednički zadatak kako laboratorija za ispitivanje, ali tako i nadležnih državnih organa, to je razvoj metoda kojim bi se mogle utvrditi prevare u vezi sa mesom.

***Ključne reči:** meso, bezbednost, kvalitet, krivotovorenje, laboratorijsko ispitivanje, akreditacija.*

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