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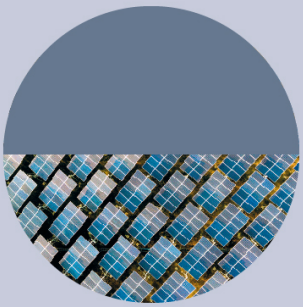

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Qualitative properties of traditionally produced dry fermented sausages from meat of the autochthonous Mangalitsa pig breed

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Abstract. The interest in autochthonous meat products from local pig breeds managed in comprehensive, sustainable breeding programs is expanding in Europe. Dry fermented sausages in Serbia and other southern European countries are highly appreciated food specialties. It is, therefore, desirable that study attempts to improve the quality of food and the security of traditional, dry sausages will result in products that are of higher added value and have quality standards that best meet the needs of contemporary customers. Meat and meat products from traditional pig breeds usually have an excellent public and media reputation, and are often regarded as better than the meat and meat products of conventionally raised pigs and crossbreed pigs. Traditional, dry fermented sausages, with their characteristic chemical contents and sensory properties, can be produced with suitable proportions of meat and backfat from the indigenous Mangalitsa pig breed. These outcomes should hopefully encourage the sustainable breeding of endangered Mangalitsa pigs, as there are market opportunities for *kulen* and *sremska* sausages.

1. Introduction

Traditional food is a significant part of European culture, identity and heritage [1] and is also strongly accepted among Serbian consumers [2]. Serbian culture is deeply rooted in a living tradition in the production of meat and meat products. Serbia is a relatively small country, but it contains numerous institutions for the production of meat and meat products [3]. Most meat establishments in the country are small enterprises that matter to the local society or region in which they are situated. Pork is traditionally the most commonly consumed meat species, correlating with pork product production, which are by far the most commonly manufactured meats [2]. In some parts of the country, beef is also highly valued and consumed more commonly, especially for religious reasons [7].

The typical gastronomic specialties in Serbia are a number of dry fermented sausages (locally known as *kulen* and *sremska*). These products, often from indigenous pig breeds, have increasing popularity as part of traditional Mediterranean foods and are increasingly consumed by Serbs and visitors alike during leisure or social occasions, when they are eaten together with other foods such as regional cheeses, bread and wine, or provided as an opportunity to discover traditional cuisine. This trend thus anticipates important possibilities for the development of these products on the market and the evolution of restaurants, snack bars or taverns, both gourmet and regional. In contrast, and in parallel, consumers are advised to reduce their daily meat consumption, including that of dry fermented sausages and meat product equivalents. This

advice can be ambiguous and it seems possible it could have damaging consequences for the meat industry and the meat market.

The interest in indigenous meat products produced from local pig breeds in extensive, sustainable breeding programs in Europe, especially in Mediterranean countries, is on the increase. Meat and meat products from traditional pig breeds are typically well-regarded by the public and media, and often are better-regarded than modern pig and crossbreed meat and meat products. A suitable combination of meat and fat from indigenous pig breeds can be used to produce traditional dried fermented sausage with authentic chemical contents and sensory characteristics. These should contribute to the maintenance of autochthonous pig breeds, provided there are market opportunities for traditional dry fermented sausage.

2. History and current status of the autochthonous pig breeds

Animal genetic resources in pig-breeding in Serbia include three breeds: Mangalitsa, Moravka and Resavka. Mangalitsa is a fatty breed, while the other two have combined production abilities (they are fatty-meat breeds). In the last thirty years, the populations of autochthonous breeds have been reduced; there was a mating in kinship and deterioration in the production performance of these breeds. Moravka and Resavka are critically endangered pig breeds and there is a real chance they will become extinct. It should be pointed out that there are efforts to increase the number of autochthonous breeds' populations, which are recognised by the relevant ministry.

Mangalitsa is an autochthonous fatty pig breed of the old Šumadinka breed of Serbia. Pigs were Serbia's main export product during the nineteenth century, particularly in the northern part of the country (today's Autonomous Province of Vojvodina) and in the region of Šumadija (central part of Serbia). Pigs were mostly fattened in the forests in Šumadija, where they consumed oak and beech acorns and other forest feed resources. In Serbia, there are three Mangalitsa breed types: *swallow-belly*, *white* and *red*. Mangalitsa is present in Germany, Austria, Hungary, Slovakia, Romania and Switzerland, as well as in Serbia. At the end of 2017, approximately 67 farmhouses with 925 sows, 605 gilts and 42 boars, of which more than 95% were swallow-belly, were registered across the country by the main breeding organisation in Serbia.

3. Geographical location and production system of Mangalitsa pigs

Farms holding Mangalitsa pigs in Serbia are in the municipalities of Subotica, Sremska Mitrovica, Bačka Palanka, Vršac, Pančevo, Ub, Obrenovac, Ljig, Valjevo, Novi Sad, Kuzmin, Šid, Surčin and Kovilj (Krčedinska ada). There are also some Mangalitsa pigs on Stara Planina Mountain (Dimitrovgrad Municipality) and around Čačak and Kraljevo. These pigs are mainly bred in free-range outdoor, extensive environments, or semi-intensive production systems. This type of pig rearing means the animals free-range on pastures within restricted fields, or in woods or orchards. Pigs can range around the community in an extensive system, which depends on the number of livestock and the size of the owner's estate, and animals are transferred into cheap and effective wooden housing during the winter. Feeding is based mainly on pasture forage and forest edibles (acorns and wild fruits). An additional daily meal is an extremely small quantity of grains per head, mainly maize. In the extensive system, sows frequently farrow in the forest, which significantly complicates productivity control and recording. Sows are also farrowed in housing under semi-intensive conditions, enabling better control. The pigs are mostly outside in the growing and fattening phases.

4. Meat quality of Mangalitsa pigs

Table 1 presents the basic data obtained for some common meat and fat quality characteristics measured in the *longissimus* muscle from Mangalitsa pigs. In publications presenting the meat quality of Mangalitsa pigs, the pH measured in the *longissimus* muscle was around 6.1 [18, 19, 20, 21, 22] and 5.6 [18, 23, 19, 24, 21, 22, 25]. In reported studies, the intramuscular fat content ranges from 2.9% to 18.2% [23, 27, 20, 21, 22, 24, 25, 28, 29, and 31]. The colour measured in CIE L, a, b colour space was approximately 45, 11.4 and 4.2 for L, a* and b*, respectively [18, 23, 19, 25], indicating a relatively dark colour of Mangalitsa meat. In the considered studies, the intra-muscular fat contents of saturated

fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) were about 35.5% 55.4% and 7.0%, respectively, with high n6/n3 ratios (9.2-37.3) [27, 19, 24, 21, 32].

Table 1. Summary of the meat quality content recorded in the Mangalitsa pig breed.

Reference	No. of animals	pH 45	pH 24	CIE[1]			IMF content	Fatty acid composition[2] (%)			
				L*	a*	b*	(%)	SFA	MUFA	PUFA	n-6/n-3
[18]	35	5.95	5.77	56	10.3	5.1	—	—	—	—	—
[23]	15	—	5.46	46	12.8	5.2	8.4	—	—	—	—
[27]	16	—	—	—	—	—	5.1	39.5	56.4	4.1	—
[19]	12	6.11	5.50	40	11.8	3.7	—	33.3	50.3	11.6	17.9
[28]	10	—	—	—	—	—	13.2	—	—	—	—
[20]	—	6.04	—	—	—	—	8.1	—	—	—	—
	—	6.32	—	—	—	—	5.5	—	—	—	—
[24]	12	6.12	5.80	—	—	—	18.2	33.9	57.2	5.9	37.3
	10	5.89	5.41	—	—	—	12.1	35.5	55.5	6.5	9.2
[21]	24	6.01	5.68	—	—	—	15.2	34.6	56.6	6.1	14.1
[29]	16	—	—	—	—	—	9.8	—	—	—	—
[22]	—	6.42	5.56	—	—	—	2.9	—	—	—	—
[25]	7	—	5.47	38	10.9	2.9	6.4	—	—	—	—
[32]	22	—	—	—	—	—	—	35.6	56.6	6.9	25.1

No. = number, pH 45= pH recorded after estimated 45 minutes, pH 24= pH measured post rigor estimated 24 hours, IMF= intramuscular fat, SFA= saturated fatty acids, MUFA= monounsaturated fatty acids, PUFA= polyunsaturated fatty acids. [1]CIE= objective colour defined by the Commission Internationale de l'Eclairage; L* higher value refers to a lighter colour; a* higher value refers to a redder colour; b* higher value refers to a more yellow colour. [2]For the compositions of fatty acids, only dietary control pigs have been considered. Control diets varied between studies to determine appropriate diet composition.

5. Use of breed and main products

Mangalitsa pigs are late maturing and are chosen for fat production. The breed has low fertility, lengthy sucking times, and very slow growth. On the other hand, however, Mangalitsa pigs are very hardy and well adapted to extensive housing conditions, where only a simple shelter from rain and snow is required. Their cost effectiveness is on par with such features, in the context of low investment in housing facilities, but large areas required for pasture and acorn feeding. Due to low production performance (low daily gain and carcass live weight), cross breeding with the Moravka, Resavka, Duroc, Hampshire or Berkshire breeds could help improve growth and carcass traits while reducing the fattening period and increasing the meat content of the carcass. Radović et al. [19] showed not significantly improved growth rates between Mangalitsa and Mangalitsa × Moravka crossbreeds (average daily gain, 267.9 *vs*. 336.9 g) and not any less carcass meat (33.2% *vs*. 33.9%). Animals not selected for the nucleus herd could be crossed with Duroc, Hampshire or Berkshire to help produce more economical meat and high-value products in the traditional style (ham and *kulen* and *sremska* sausages) that could be marketed as highly valuable organic products or geographically protected products. Dry fermented sausages are long-established meat products, and today there are numerous national varieties. *Kulen* [33, 34] and *sremska* sausage are the most common types of traditional dry fermented sausages in Serbia. Figure 1 shows the main traditional *kulen* and *sremska* dry fermented sausage production processes.

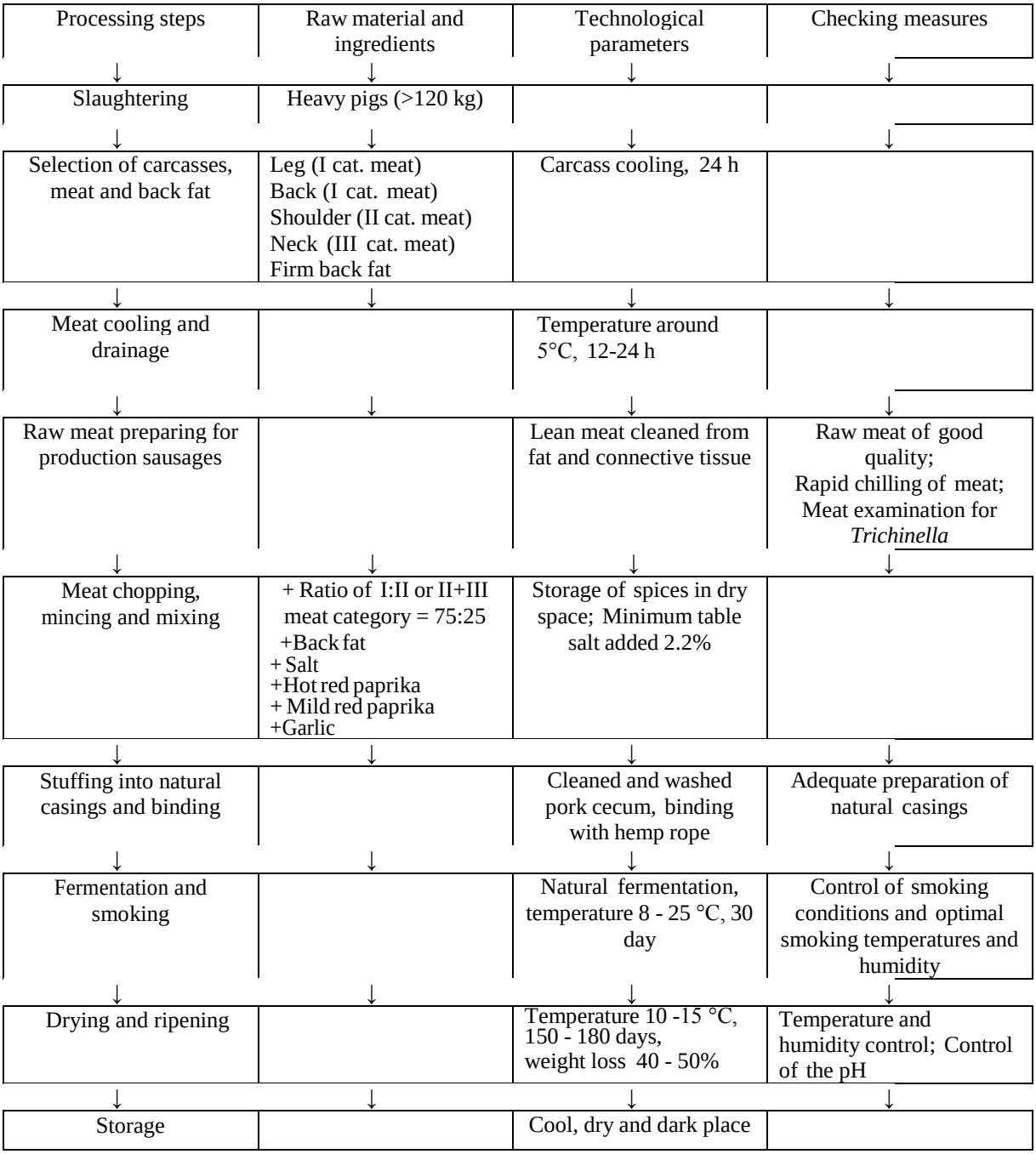

Figure 1. Traditional *kulen* and *sremska* dry fermented sausage production processes

6. Kulen – traditional dry fermented sausage

Kulen is a well-known and popular traditional dry fermented sausage in Northern Serbia (Srem, Bačka) and Croatia (Slavonija, Baranja). For all variants of this product, high-quality meat is

used from mature pigs with relatively low water content, intense red colour and firm consistency. The meat used is mainly leg, shoulder and some neck pieces, but also with a small percentage of firm backfat tissue. Muscle and adipose tissue (75:25) are typically cut to 10 mm granulation in a cutter. The chopped meat is transferred to a mixer and the other filling ingredients are added: 2.3 % table salt, 0.4 % saccharose, 0.3 % garlic (powder), 0.3 % pepper and 0.8 % ground sweet and hot red paprika. Then the filling is firmly stuffed into natural pig colon casings. Sausages are hung on rods and left 20 to 24 h at 18 ºC for the surface to dry. After that, sausages are moved to a traditional smokehouse. Sausage production, smoking and maturation occur during winter (December to February). The temperature of the smokehouse is from 10 to 15 ºC and the humidity is between 75 and 90%. Subsequently, sausages are matured at 10 to 12 ºC and in industrial conditions, in a controlled drying chamber until the end of the manufacturing process, which lasts 90 days.

7. Sremska – traditional dry fermented sausage

Sremska sausage is a traditionally produced Serbian dry fermented sausage from the northwest part of Serbia (Srem region), where it was produced in village households. It is made from ground pig meat and backfat (approximately 8 mm) and mixed with salt and spices. *Sremska* sausage has a pronounced red colour, tender texture, slightly hot taste, fermented meat door and mild spice and smoke notes [35, 36].

Sremska sausage was traditionally manufactured in smokehouses during winter [35]. The manufacturing technology for most dry fermented sausages is now based on modern technology, controlled maturing rooms and fast cure methods, leading to reduced manufacturing time and safer product [4, 5]. Industrial *sremska* sausages acquire exceptional appearance characteristics, but typically, their other sensory attributes are poor. They have, above all, a strong acidic flavour that is largely unacceptable to consumers [7]. On the other hand, traditional *sremska* dry fermented sausages manufactured at low temperatures by spontaneous meat fermentation are of very high quality [31].

For industrial manufacture of *sremska* sausage, shoulder meat and backfat from Mangalitsa pigs (approximate live weight 115-120 kg) is minced in the ratio of 75:25 then blended in a cutter. The cut meat/backfat is blended with other components: 2.2% NaCl, 0.3% sugar, 0.17% garlic (powder), 0.55% hot red paprika (powder) and 0.55% sweet paprika (powder). No starter culture is added, so fermentation is spontaneous. The sausage filling (approx. 700-800 g) is stuffed into natural casings of about 32 mm in diameter (pig small intestines). Sausages are held in a cold store (4±1 °C) for 12 hours for their surfaces to dry and then placed in a traditional smokehouse. The ripening is as follows: the first stage lasts 14 days in a traditional smokehouse at 10-15 °C with 75-90 % relative humidity (RH), where the sausages are smoked for 6 hours each day; during the next 7 days, sausages are processed in a drying room at 14-16 °C with about 75 % RH, reaching about 35.0 % humidity. The complete processing time is 21 days.

Current knowledge of traditionally manufactured *sremska* sausage is restricted and their quality is very variable as there is very little uniformity in the manufacturing practices applied by distinct meat and home manufacturers. Within the current trends of encouraging and supporting successful traditional food manufacturing technologies and in order to maintain the quality of traditional *sremska* sausage, the physico-chemical qualities of this sausage manufactured in a traditional smokehouse have been studied.

8. Quality properties of *kulen* and *sremska* dry fermented sausages

Tables 2 and 3 present the basic physico-chemical properties of *kulen* and *sremska* dry fermented sausages, respectively.

Table 2. Physico-chemical properties of *kulen* traditional dry fermented sausage

Reference	Moisture	Protein	Fat	Ash	pH	Fatty acid composition (%)				Cholesterol
						SFA	PUFA	MUFA	n-6/n-3	
	%	%	%	%						mg/100 g

[37]	27.58	24.14	43.36	4.09	-	39.10	11.57	49.34	25.19	62.07
[34]	-	33.75	20.86	5.37	-	39.77	14.07	46.16	-	68.14
[38]	37.8	31.0	24.2	-	5.22	-	-	-	-	-
[33]	38.06	34.62	16.98	5.34	5.12	39.00	12.92	48.44	22.05	68.64
	37.92	35.79	15.02	5.25	5.05	42.21	13.49	45.77	18.87	61.48
	35.70	34.24	21.00	5.67	5.03	40.72	13.46	46.19	22.25	66.00
	37.55	35.63	14.98	5.91	4.99	40.44	12.93	46.99	23.02	64.76
	38.78	35.04	17.10	5.46	4.86	40.29	14.80	45.47	17.57	79.62
[39]	23.62	27.20	39.30	4.61	5.24	39.22	8.80	51.97	16.96	50.16

SFA= saturated fatty acids, MUFA= monounsaturated fatty acids, PUFA= polyunsaturated fatty acids.

Table 3. Physico-chemical properties of *sremska* traditional dry fermented sausage

Reference	Moisture	Protein	Fat	Ash	pH	Fatty acid composition (%)				Cholesterol
						SFA	PUFA	MUFA	n-6/n-3	
	%	%	%	%						mg/100 g
[36]	27.89	21.46	44.78	6.24	5.48	-	-	-	-	-
	25.11	23.09	44.98	6.05	5.50	-	-	-	-	-
[37]	28.17	22.04	43.83	5.08	-	37.19	12.07	50.74	26.39	60.72
[39]	21.67	29.16	39.45	5.25	5.25	38.40	8.78	52.80	14.38	59.65
	39.41	28.04	22.00	4.72	4.72	39.71	16.78	43.49	35.86	64.92
	33.30	23.20	34.92	4.73	4.73	40.94	14.00	45.04	37.36	53.47

SFA= saturated fatty acids, MUFA= monounsaturated fatty acids, PUFA= polyunsaturated fatty acids.

8.1 Basic Chemical Composition

The protein content of *sremska* sausage was 21.46% to 29.16% **[**36**,** 37, 39**].** The highest protein content in *kulen* sausage was 35.79% **[**33**]**. *Kulen* and *sremska* sausages made from the meat of Mangalitsa pigs had the lowest moisture content (21.67% and 23.62%, respectively), and the highest fat content (44.98% and 43.46%, respectively) among other sausages from other pig breeds. Some studies have already shown that Mangalitsa meat (m. *longissimus*) has a reduced protein content compared to the meat of commercial pig breeds [30, 40], thus explaining in part the moderately reduced protein content in *kulen* and *sremska* sausages. The low moisture content is typical of similar products from Greece, Hungary and Croatia **[**41**]**, and is a consequence not only of drying, but also the relatively high fat content. The ash contents of the *kulen* and *sremska* sausages varied, ranging from 4.09% to 6.24%. The pH of *sremska* sausages ranged from 4.72 to 5.50 [39]. At the beginning of the ripening process of traditional *kulen*, the pH ranged from 5.6 to 5.8, which corresponds to the pH of cooled pork meat, and subsequently, the sausage pH starts to decline [42]. Certainly, the sugars (fructose, glucose, sucrose) that are the paprika spice's natural components have a major impact on the pH value of maturing *kulen*. According to literature data [43], ground paprika contains about 15% sugar, whereas the complete sugar content of local ground paprika is greater and about 25%.

In Italy [44, 45], Greece [46], Spain [6] and France [8], the naturally dry fermented sausages from the Mediterranean countries are usually characterised by low acidity with a final pH range from 5.2 to 6.4.

8.2 Fatty Acid Composition

Tables 2 and 3 show the fatty acid profiles of *kulen* and *sremska* sausages. The levels of PUFA in other dry fermented sausages made from the Mangalitsa pig breed were around 8.78 and 8.80% and 16.78 and 14.80%, respectively **[**33,39**]**. Lower complete n-3 PUFA content and reduced levels of total n-6 PUFA generated these distinctions. These led to lower n-6/n-3 ratios in dry fermented *kulen* (17.57) and *sremska* (14.38) sausages. In spite of that though, the n-6/n-3 ratios in other types of sausages were between 25 and 37. In different studies, Hoz [9] and Valencia et al. [10] found reduced ratios of n-6/n-3 fatty acids (12.05 and 13.86, respectively) in their control groups of dry fermented sausages. MUFA values ranged from 43.49/45.47% to 52.80/51.97%. The *sremska* and *kulen* sausages made from the meat of Mangalitsa pigs contain higher levels of MUFA than other types of sausages. Additionally, oleic acid (C18:1 cis-9), cis-vaccenic acid, (C18:1 cis-11) and palmitic acid (C16:1) levels in these types of sausages were considerably higher than in the other types **[**39**].** *Kulen* and *sremska* sausages made from the meat of Mangalitsa pig breed have higher unsaturated fatty acids (USFA) and lower SFA levels. Overall, USFA contents are significantly higher in sausages made from the meat of Mangalitsa pig breeds **[**39**]**.

8.3 Cholesterol Content

The cholesterol content in *kulen* and *sremska* sausages at the conclusion of the production process ranges from 53.47/50.16 mg/100 g to 64.92/79.62 mg/100 g [33, 39]. Cholesterol levels have been established between 94.8 and 110.5 mg per 100 g for Salami Milano [11]. For Italian salami, cholesterol contents of between 48 mg and 57 mg/100 g were measured by Baggio and Bragagnolo [12]. Pleadin et al. [13] noticed that the average cholesterol content was from 58.48 mg/100 g to 105.24 mg/100 g in sausages that were industrially prepared, while in home-made sausages, the cholesterol content reached 75.07 mg/100 g.

8.4 Sensory Properties

Kulen and *sremska* sausage colour is correlated with the colour of the meat used. Mangalitsa pig meat is darker than other pork (for example, Swedish Landrace and Moravka); therefore, sausages made from the meat of Mangalitsa breed were assessed as too dark, and received a somewhat lower grade than the other sausage types [39]. Odour was the sensory indicator most affected by the pig breed. The most characteristic and finest sausages are made from Mangalitsa breed meat. The odour of this sausage type was rich and very pronounced, and received a much higher grade than other kinds of sausages [39]. Sausages made only from the meat of Mangalitsa breed (*kulen* and *sremska*) had better sensory characteristics, thus confirming the work of Radman et al. [14], who observed some pig breeds are appropriate for dry fermented pork sausage manufacture. Relationships have been reported between physical meat quality characteristics and sensory characteristics, such as muscle fibre and overall tenderness [15, 16], and between quantity and composition of intramuscular fat and flavour [26]. Flavour is, however, a very sophisticated attribute of meat palatability [26] and its relation to fat content and structure varies with cattle breed [16].

9. Sustainable development: economic, environmental and social points of view

Serb consumers greatly appreciate the meat, adipose tissue and meat products from Mangalitsa pigs, and scientific effort is not limited to just preserve the breed as such, but also to exploit the animal's potential for human consumption. The production of these pork specialties plays important roles based on the three pillars of sustainable development: economic, environmental and social. The utilisation of all parts of livestock animals, with minimal losses and food waste, is of great financial and environmental significance. This sustainable strategy also helps to provide farmers with extra revenues in an economic and environmental sense. In addition, indigenous livestock production is a significant financial activity in the eastern and western regions of Serbia (where the main indigenous pig industry remains crucial in gross domestic product (GDP) terms), although it also exists at a smaller level throughout the country. The various meat companies and their extension businesses also help to attract individuals to live in and

remain in rural communities and areas, thereby stopping the current rural exodus to metropolitan areas and helping to promote (now booming) local tourism.

Food safety and quality are major concerns and European Union (EU) policy priorities, as highlighted earlier in the White Paper on Food Safety, Agenda 2000, as well as in Horizon 2020 – the EU Research and Innovation Framework Programme. The relevant knowledge on science-based features of these sausages will, therefore, be submitted to formal accreditation focused on traditional products through Protected Geographical Indication (PGI). This will contribute to improving sausage quality and to rationalising any health claims more effectively, with both helping to expand the market niche and the economic value of the foods [17].

Every effort to enhance the quality and safety of foods like traditional dry fermented sausages and other products is always worthy. Accordingly, scientifically sound work on defining traditional dry fermented sausages derived from a wide range of technological studies (rigorously designed and on products developed to be implemented in the meat sector) and in cooperation with the numerous regional meat producers and suppliers is essential. For example, the use of different salt levels, various ingredients and raw materials, change of sausage diameter, smoke type and duration, and animal genotype are examples of relevant technological parameters than need to be assessed throughout the manufacturing process (for example at start of processing, during maturation, in final product and during distinct storage stages). Maturation times and temperatures and the use of suitable preservative compounds (e.g. acetic or lactic acids) are worthy of study.

This type of scientific effort by the research community is expected to result in a significant improvement in the quality of dry fermented sausages and other meat products, and thus should contribute to market expansion of these products [17]. This will in turn lead to numerous beneficial effects such as enhancing South European and Mediterranean foods and their quality, preventing rural exodus to urban areas and enhancing the economy as a whole – upstream (stimulating autochthonous pig breeds) and downstream (incitement to the meat industry).

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