Chapter

Autochthonous Breeds of Republic of Serbia and Valuation in Food Industry: Opportunities and Challenges

Čedomir Radović, Milica Petrović, Marija Gogić, Dragan Radojković, Vladimir Živković, Nenad Stoiljković and Radomir Savić

Abstract

Climate change and the emergence of new animal diseases emphasize the need to maintain and conserve plant and animal resources because of their adaptive capacity. For hundreds of millions of poor rural households, livestock production and crop farming are a key resource for life. Livestock production has great contribution and is vitally important for the life and safety of crop production. Conservation of animal genetic resources is not easy and simple, but it is of concern that in the past some animal genetic resources have been lost before their characterization and their genetic potential has not been studied. It is known that with the loss of a single breed or strain, the genetic diversity contained within also disappears. That is why it is necessary to continuously work on the conservation of animal genetic resources using various methods of conservation. The preservation and improvement of livestock production and animal genetic diversity, the preservation and the development of locally adapted (autochthonous) new breeds, as well as the preservation of genetically diverse populations provide society with a greater range of options to meet future challenges and further develop agriculture.

Keywords: animal genetic resources, phenotype, Mangalitsa, Moravka, Resavka

1. Introduction

Pig farming in the Republic of Serbia has been of great importance since ancient times and represents an important branch of agricultural production. The importance of pig breeding in livestock production and the overall economy of Serbia comes from its economic and biological importance. Opportunities and conditions for growing and improving pig production are very favorable. Agricultural biodiversity is a product of thousands of years of activity in which people are trying to meet their needs in a wide range of social, climatic, and ecological conditions. Well-adapted and developed livestock breeding is an essential element of the agricultural production system; it is especially important in difficult conditions when the plant production in the agroecosystem cannot maintain and increase its productivity and adapt to changing circumstances and is crucial for the food safety of the population. The preservation and improvement of livestock production and animal genetic diversity, the preservation of and the development of locally adapted (autochthonous) new breeds, as well as the preservation of genetically diverse populations provide society with a greater range of options to meet future challenges and further develop agriculture. Responsible management of agricultural biodiversity in the world is becoming an increasing challenge for the international community, especially in the livestock sector, as it goes through dramatic changes by intensifying production, trying to respond to growing demands for increased production of meat, milk, and eggs. A wide range of many different animal genetic resources that correspond to and meet different human needs and desires is crucial for our adaptation and development of the agricultural production system. Climate change and the emergence of new animal diseases emphasize the need to maintain and conserve plant and animal resources because of their adaptive capacity. For hundreds of millions of poor rural households, livestock production and crop farming are a key resource for life. Livestock production has great contribution and is vitally important for the life and safety of crop production. Conservation of animal genetic resources is not easy and simple, but it is of concern that in the past some animal genetic resources have been lost before their characterization and their genetic potential has not been studied. It is known that with the loss of a single breed or strain, the genetic diversity contained within also disappears. That is why it is necessary to continuously work on the conservation of animal genetic resources using various methods of conservation.

In recent years, interest in autochthonous breeds has increased, not only for the purpose of preserving their genes but also for obtaining raw materials for the production of traditional dry meat products (Kulen sausage, bacon, pork skin crackling, etc.). This would allow the development of rural areas and small family farms.

2. The emergence of pig breeds: Mangalitsa (ML), Moravka (M), and Resavka

2.1 Mangalitsa

The first description for *Mangalitsa* found in scientific literature is from [1] 1886 in the journal *Težak*. *Mangalitsa* is improved Šumadinka breed, that is, Šumadinka breed which became more productive in improved conditions of growing and, above all, nutrition, care, and housing [2]. However, [3] states that the Mangalitsa was formed by the improvement of Šumadinka but also crossing with the Bakonian pig cultivated in Hungary. Mangalitsa was formed by crossing of the extinct Hungarian and Mediterranean breeds of pigs [4].

Genetic links between Hungarian Mangalitsa that are farmed in different geographic locations have been studied by 10 microsatellite markers. Estimated distances (Da, Ds, Fst) were the lowest between Swallow and White Mangalitsa, while Red Mangalitsa showed the highest genetic distance from the previous two breeds [5]. Based on the structure of DNA strains of the Mangalitsa pig, researchers have found that strains should be considered as individual breeds (Swallow Belly, White and Red Mangalitsa). Mangalitsa is a late breed of pigs, a fatty type with more strains within the breed (Swallow Belly, White and Red Mangalitsa). The occurrence of inbreeding is one of the main causes of poor production performance of this breed and has a negative impact on the condition of the population. There is a tendency to overcome these problems, which requires more systematic breeding and selection work (**Figure 1**).

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Figure 1.
Swallow Belly Mangalitsa (Foto Č. Radović).

Figure 2.
Moravka (Foto Č. Radović).

2.2 Moravka

Moravka is a domestic pig breed cultivated mainly in the region of Svilajnac from which it spread throughout Serbia. It is the product of an unplanned crossing of Šumadinka and Berkshire pig breeds. Many years of random crossing and non-systematic selection have led to one stabilized type that became a breed. Random unplanned cultivation (unplanned use in reproduction and taking no consideration of relations) until the Second World War has led to further weakening of its body constitution and production. It imposed the adoption of certain measures from 1953 to 1958, such as the import of the Cornwall and its use for the improvement of Moravka. Positive results have been achieved in improving the properties of crosses. However, initiated work on the improvement of national pig breeding was short-lived (**Figure 2**).

2.3 Resavka

Resavka was created in the same area of Serbia but in much lower numbers than Moravka. It was reared especially in the valley of the river Resava. It was also formed by the non-systematic crossing of domestic breeds (Šumadinka and Mangalitsa) with Berkshire breed. On the one hand, single color black animals were chosen and, on the other, spotted animals, which resulted in stabilization of two types or pig breeds. The production characteristics of Resavka are similar to properties of the Moravka breed (**Figure 3**).

Figure 3.
Resavka (Foto Č. Radović).

3. The size of the population and body development of pigs of indigenous breeds

3.1 Mangalitsa

The size of the population has changed over the years (**Table 1**), indicating the absence of stability in the breeding of Mangalitsa. Based on the data from 2017, the calculated effective population size is N = 193.46, which means that the breed is highly endangered. The number of animals under productivity control is insignificant, which represents a limiting factor for the genetic improvement of this breed (**Tables 2** and **3**).

In critically endangered populations, there is a loss of genetic variability, and the level of inbreeding is increased. This results in an increase in the frequency of recessive genotypes (sometimes undesirable) which reduces vitality, resistance, fertility, and animal growth. The level of inbreeding is related to the actual and effective size of the population. With the increase in the effective size of the population, the level of inbreeding is reduced and vice versa.

The data on the official website (http://efabis.tzv.fal.de/) show the following numbers (Republic of Serbia) for female and male breeding animals of Mangalitsa, Moravka, and Resavka breeds in 2014: 247 and 35, 18 and 4, and 6 and 2, respectively. According to the rulebook on incentives for the conservation of animal genetic resources [6], incentives are given for breeding sows, breeding boars, and breeding gilts of autochthonous breeds of Mangalitsa, Moravka, and Resavka. One of the conditions for obtaining incentives was the selection control, certified by the local, regional, and national breeding organizations. On the other hand, the report and the results of the implementation of the breeding program in 2014 in Central Serbia (Institute for Animal Husbandry, Belgrade,

Year	2009	2012	2013	2014	2015	2016	2017
Population	1000	100	300	300	1000	2000	2000
Breeding females	600	90	203	247	698	1914	1480
Breeding males	50	2	24	35	21	50	50
Breeding females registered in the herdbook		90	153	247	290	388	523

The calculated effective size of the Moravka population for 2017 is No = 56.78, which means that the breed is highly endangered.

Table 1.
Mangalitsa population size (EFABIS, European farm animal biodiversity information system. Available from http://efabis.vet.agri.ee/).

Year	2009	2012	2013	2014	2015	2016	2017
Population	100	150	100	300	100	500	500
Breeding females	90	140	14	18	95	257	265
Breeding males	10	10	2	4	1	15	15
Breeding females registered in the herdbook			13	18		84	184

The calculated effective size of the Resavka population for 2017 is No = 41.79, which means that the breed is highly endangered.

Table 2.
Moravka population size (EFABIS, European farm animal biodiversity information system. Available from http://efabis.vet.agri.ee/).

Year	2009	2012	2013	2014	2015	2016	2017
Population	40	50	5	8	16	64	75
Breeding females	30	40	4	6	15	60	65
Breeding males	10	10	1	2	1	4	5
Breeding females registered in the herdbook						20	18

Table 3.
Resavka population size (EFABIS, European farm animal biodiversity information system. Available from http://efabis.vet.agri.ee/).

Body measure	White Mangalitsa		Swallow Belly Mangalitsa		Red Mangalitsa	
	Boar	Sow	Boar	Sow	Boar	Sow
Withers height (cm)	83	81	78	78	88	82
Chest circumference (cm)	155	155	140	150	154	150
Body length (cm)	96	97	95	98	104	98
Body weight (kg)	190	165	165	170	220	180

Table 4.
Body dimensions/measures of adult animals (2–3 years old) of the Mangalitsa breed [8].

2015 [7]) show that only 102 litters of all three indigenous breeds of pigs were under control. A small number of breeding animals are under control; there is no interest of breeders and local breeding organizations in fattening autochthonous pig breeds. The records are incomplete, animals without pedigree are purchased, and there are no standard and selection criteria for autochthonous breeds.

Body development of adult animals of Mangalitsa breed (**Table 4**) shows that sows and boars of Red Mangalitsa have a higher body weight at the age of 2–3 years than the other two strains. Animals of Swallow Belly strain are smaller in size than the White and Red Mangalitsa strain.

Table 5 shows the body dimensions of adult animals of the Moravka breed. The body weight of the boars and sows varies in a wide range (72–152 and 70–160 kg, respectively). The body is over 32 and 33% longer than the withers height.

According to research [10] the average weight of sows (age 3–5 years) was 77.67 kg and height of the withers 63.83 cm. The average fertility of sows was 7.20 piglets.

Body measure	Sows	Boars
Withers height (cm)	62.40	63.44
Chest circumference (cm)	107.02	112.20
Body length (cm)	82.55	84.64
Body weight (kg)	93.70	98.00

Table 5.
Body dimensions/measures of the sows and boars of the Moravka breed (older than 2 years [9]).

4. Reproduction performance

The average age of the primiparous Swallow Belly Mangalitsa gilts differs between the herds, the rearing conditions, nutrition, and care—from 615.6 days [11] up to 966.6 days [12]. In the herds of Swallow Belly Mangalitsa covered by the project, the age of all controlled sows at first partus (**Table 4**) ranged from 430 (1.18 years, Breeder A) to 588 days (1.61 years, Breeder B).

In 90% of cases, with White and Swallow Belly Mangalitsa, the duration of gestation period is 113–117 days [13]. The same author concludes that the duration of the gestation does not depend on the age of sows and the number of piglets in the litter. Also, Petrović et al. [12] find that the herd, sow age, and mating season have no significant influence on the duration of gestation.

There is a significant variation in the average duration of the reproductive cycle of Mangalitsa sows between the herds, age of the sow, and the parity (**Table 6**).

The fertility of sows expressed by the size of the litter at birth and weaning varies between the herds, the age of sows, and the seasons. The diet, based mainly on corn, limits the reproductive performance of sows [14]. The sows of White, Swallow Belly, and Red Mangalitsa breed in Hungary gave birth on average to 6.73 and reared 5.92 piglets [15].

Studies by domestic authors show that the fertility of Mangalitsa is between 1 and 12 piglets in the litter or an average of about 5 piglets. In 9 of the 14 years, the fertility of the Swallow Belly Mangalitsa was higher than 5.50 piglets per litter [2]. Swallow Belly Mangalitsa reared in extensive conditions gives birth in the first partus from 3 to 4 and in subsequent parities from 5 to 6 piglets [16]. Recent studies show that the average number of live-born piglets is below 5 (**Table 6**).

Trait	[11]	[12]		[17]	[7]
		Herd 1	Herd 2		
Duration of gestation (days)	115.37	115.34	114.36		
Duration of reproduction cycle (days)	212.10	209.78	182.14		
Number of live-born piglets	4.48	4.54	4.87	4.82	4.73
Total born piglets	4.76	4.93	5.16	5.32	4.96
Number of reared piglets	3.85	3.83	4.80	4.92*	4.48

**Number of piglets per weaned litter*

Table 6.
Variability of reproductive performance of swallow belly Mangalitsa.

5. Housing systems, nutrition, and reproduction performance

Farming of autochthonous breeds in the Republic of Serbia is mostly in an open system (in forests using the grazing system). Only in the period of farrowing and rearing of piglets are sows housed in the facility. The diet for lactating sows consists of corn, barley (2.5 kg/sows), and kitchen waste. During the year when acorn is available, pigs are not given the corn. Pigs consume plant mass in the forest, wild fruits, roots, insects, etc. Piglets are fed about 2 kg of food. Fattening is carried out from August to November by adding corn in the amount of 3–4 kg/animal. Barley is added to the diet if necessary. In the winter period, alfalfa is added to diet for sows. Other categories of pigs receive maize (ground or on Cobb), in addition to plant ingredients from the nature.

Pig nutrition in an extensive system of keeping involves feeding pigs in pastures, in the forests, and in the winter additionally with corn, barley, and other cereals. Pig grazing positively affects the development of the digestive tract of the animal, allowing them to consume larger amounts of food. This is of particular importance for the feeding of lactating sows. Grazing can meet the needs of pregnant sows, but not sows during lactation. Concentrated and voluminous nutrients (beetroot, potato, pumpkin, etc.) can be added to sows' diet during lactation.

Keeping pigs in the forest means that animals consume the natural food they find themselves. The pigs' nutritional requirements cannot be met only by what they find in the forest, but it can be combined with pastures and fields after harvest. This way of keeping is environmentally friendly as it provides the natural way of rearing indigenous breeds of pigs. Movement of pigs in forest and pasture areas provides a positive impact on the welfare, health of pigs, and the acquisition of quality raw materials for further processing.

Pigs that are reared in the forest mostly consume acorn (oak and beech), wild chestnuts, wild fruits, roots, insects, worms, etc. During the winter period, but also in the diet of pregnant and sows in lactation, grains and voluminous nutrients should be added. Also, with this rearing system, financial investments in the construction of expensive facilities and food costs are lower. The benefits of using acorn in pig nutrition are in its chemical composition and antioxidant properties. Acorn is rich in tocopherols and tannins. Feeding the pigs with acorns at the final stage of the fattening positively influences the fatty acid composition of the muscles. Beech acorn is nutritionally similar to corn and is considered good feed stuff in pig fattening. In a closed housing/rearing system of fattening, it can be crushed or ground. Oak acorn is less nutritious than beech because it contains more cellulose and less protein. Daily quantities of acorn per animal depend on the composition of the meal, i.e., the share of other nutrients. In the literature, daily amounts are reported from 3.1 to 3.6 kg [18] up to 4 kg [19] and from 7 to 10 kg of acorn [20]. Pigs also consume wild chestnut and sweet chestnut. The nutritional value of chestnut is similar to the acorn.

Reproductive properties of 192 Swallow Belly Mangalitsa sows and size of 536 litters in four breeders (A, B, V, and G) are shown in **Table 7**. The number of litter per sow ranged from 2.00 (Breeder A) to 3.70 (Breeder V). Breeder A in the parity structure has 57.81% of the firstborn, which means he is expending his herd. Contrary to Breeders A, B, and G, Breeder V has only sows with more than one parity (sows with 2–5 litters).

If the population is reproductive inactive and if the population includes fewer individuals per year, the population is compromised.

The average number of live-born piglets per litter ranges from 3.18 (Breeder B) to 4.46 (Breeder V). The fertility of all sows in four herds was 3.92 live-born piglets. The sows farrowed 1 to 7 piglets per litter. The difference in the average number of live-born piglets LBP (**Table 7**) between the breeders ranges from 0.38 (difference between A and V) to 1.28 piglets (difference between B and V). The share of stillborn piglets is in the range of 1.45 (Breeder A) to 9.14% (Breeder B). In the free rearing/housing system, sows are often separated from the herd, looking for a protected area to give birth to piglets, which are exposed to dangers and death. If farrowing is done within the facilities, it is possible to determine the share of stillborn piglets more reliably. The sows reared on average 3.76 pigs with a variation of 3.00 (Breeder B) to 4.29 (Breeder V). The difference in the average number of reared piglets between Breeder A and V (0.25 piglets) is not statistically significant. Breeders B and G have sown whose fertility is below the average in all four herds (**Table 8**).

The average fertility values of the primiparous females are shown in **Table 9**.

In the first partus, sows had an average of 3.54 piglets, of which 3.46 were live-born. The average number of reared piglets was 3.35 or 96.8% of the total born

Traits	Breeder[1]			
	A	B	V	G
Number of sows under control	64	38	20	70
Number of litters	127	131	74	204
Litters per sow	2.00	3.45	3.70	2.91
Share of first litters (%)	57.81	21.05	0	32.86
Age at first farrowing (A1F, years)	1.18	1.61	1.20	1.29
Number of live-born piglets (LBP)	4.08	3.18	4.46	3.62
Total born piglets (TBP)	4.14	3.50	4.65	3.76
Share of stillborn piglets (%)	1.45	9.14	4.09	3.72
Number of reared piglets (RP)	4.04	3.00	4.29	3.41
Piglet losses during lactation (%)	0.98	5.66	3.81	5.80

[1]*Belgrade Region, Breeders A and G; Mačva Region, Breeder V; Moravica Region, Breeder B*

Table 7.
Average values of fertility traits of swallow belly Mangalitsa sows (samples from the project).

Breeder	Number of litters	LBP	TBP	RP
A-B	-1.45^{***}	$+0.90^{***}$	$+0.64^{**}$	$+1.04^{***}$
A-V	-1.70^{***}	-0.38^{*}	-0.51^{**}	-0.25^{ns}
A-G	-0.91^{**}	$+0.46^{**}$	$+0.38^{*}$	$+0.63^{***}$
B-V	-0.25^{ns}	-1.28^{***}	-1.15^{***}	-1.29^{***}
B-G	$+0.54^{ns}$	-0.44^{*}	-0.26^{ns}	-0.41^{*}
V-G	$+0.79^{*}$	$+0.84^{***}$	$+0.89^{***}$	$+0.88^{***}$

$^{ns}P \geq 0.05$
$^{*}P \leq 0.05$
$^{**}P \leq 0.01$
$^{***}P \leq 0.001$

Table 8.
Significance of differences between the arithmetic mean of the fertility traits of the Swallow Belly Mangalitsa sows between the breeders.

Traits	Breeder			Average
	A	B	G	
Number of sows under control	37	8	23	68
Age at first farrowing (A1F, years)	1.25	1.80	1.32	1.34
Number of live-born piglets (LBP)	3.95	2.88	2.87	3.46
Total born piglets (TBP)	3.97	2.88	3.09	3.54
Number of reared piglets (RP)	3.86	2.88	2.70	3.35

Table 9.
Average values of fertility traits of primiparous Swallow Belly Mangalitsa sows (samples from the project).

Breeder	A1F (years)	LBP	TBP	RP
A-B	-0.55^{***}	$+1.07^{***}$	$+1.09^{**}$	$+0.98^{**}$
A-G	-0.07^{*}	$+1.08^{***}$	$+0.88^{***}$	$+1.16^{***}$
B-G	$+0.48^{**}$	$+0.01^{ns}$	-0.21^{ns}	$+0.18^{ns}$

$^{ns}P \geq 0.05$
$^{*}P \leq 0.05$
$^{**}P \leq 0.01$
$^{***}P \leq 0.001$

Table 10.
Significance of differences in arithmetical means of fertility traits of primiparous Swallow Belly Mangalitsa sows between the breeders.

piglets. The number of live-born piglets ranged between the litters on average from 2.87 (Breeder G) to 3.95 (Breeder A), total born piglets from 2.88 (Breeder B) to 3.97 (Breeder A), and reared from 2.70 (Breeder G) to 3.86 (Breeder A).

Fertility of primiparous sows of Breeder A was higher by 1.07 and 1.08 live-born piglets and 0.98 and 1.16 reared piglets than in the case of Breeders B and G (**Table 10**). The average size of the litter (at birth and weaning) of the primiparous sows of Breeders B and G was not significant.

6. Quality of carcass sides and meat of autochthonous breeds

6.1 The impact of the rearing system and nutrition

Mangalitsa is a typical fatty pig breed, which has about 30–35% of meat in carcass sides [4, 21–23]. Moravka is a breed of combined production abilities that has more meat in carcass sides and less fat than Mangalitsa [22, 23].Today autochthonous breeds are reared in an open system or farm conditions and fed in a traditional way or with complete feed mixtures.

Study of the influence of different methods of rearing and nutrition on the quality of carcass side and meat of Swallow Belly Mangalitsa was performed on 23 fatteners (male castrated animals, [24]). The first group was kept in an open system in the forest, mainly grazing and consuming roots and forest fruits with the addition of smaller quantities of corn (up to 0.3 kg/animal/day). The second group was reared in farm conditions with free ranges and fed with two complete feed mixtures (the first mixture with 15 and the other with 13% protein content). Animals were slaughtered in the same slaughterhouse. On the slaughter line, linear measures of warm carcass sides were taken, and the pH of the long *musculus* *longissimus dorsi* (MLD) was measured in the first hour after slaughter. A partial dissection of left chilled carcass sides was carried out according to the EU reference method [25].

The total mass and mass of muscle tissue in the four main carcass parts depended on the mass of cold carcass sides. The system of rearing and nutrition of Swallow Belly Mangalitsa fatteners showed no impact on most of the carcass side traits. However, it influenced the age of slaughterers at slaughter. The fatteners kept in the open system had an average of 739.0 days at slaughter, compared to 348.8 days in the closed system.

Of the total weight of the ham, the muscle tissue was 45.58 (open system) and 48.32% (closed system). A similar proportion of muscle tissue was found in the shoulder (47.90 and 45.67%). The share of muscle tissue in the back loin and belly rib carcass parts of fatteners reared in the closed system was higher (28.87 and 28.06%) than the open-system fattening (25.59 and 25.12%), but the differences were not significant ($R > 0.05$).

Fatteners kept in the closed system had by 2.53% more muscle tissue in carcass sides (mean 37.07%) than those reared in the open system (mean 34.54%); however, the established difference was not significant. MLD of fatteners reared in the closed system showed significantly higher water content (by 2.22%) and lower total fat (by 2.64%) than the open holding system. Statistically significantly higher ash content (by 0.07) was established in MLD of fatteners kept in the closed rearing system. The average pH_1 values indicate that both groups of fatteners had normal-quality meat with a higher variability of the trait in animals reared in the closed system, so that the difference of 0.28 was not significant.

6.2 The impact of breed, pig gender, and breeding methods

The study of the influence of the breed and gender of the fatteners on the growth traits, the composition of the carcass sides, and the quality of the meat was carried out on the animals reared in the same conditions [26]. The castrated males and females of the Swallow Belly Mangalitsa (LM, n = 19) and Moravka (M, n = 23) breeds were grown in the same herd in farm conditions. Each animal was provided with a surface area of 3.57 m^2. The fattening began with about 20–22 kg and lasted until animals reached 93–124 kg body weight. During the fattening, the animals were fed with two complete mixtures consisting of maize silage, livestock flour, soybean meal, sunflower meal, synthetic lysine, mineral nutrients, and premixes.

The average slaughter weight of LM and M was 103.67 ± 1.30 and 103.53 ± 1.21 kg and age 339.08 and 331.35 days, respectively. In the performed researches, the average daily gain from birth to the end of the fattening was lower and did not differ between LM and M (307 and 316 g, $P > 0.05$).

Fatteners of Moravka breed had a higher average weight of the back loin part of the carcass side (by 0.731 kg) and the weight of the subcutaneous fat tissue with skin (for 0.355 kg) than the Swallow Belly Mangalitsa breed (**Table 11**). The share of muscle tissue in this carcass part in the total weight of muscle tissue in four parts of the carcass side was higher in the animals of the Moravka breed (by 2.18%). The greater share of bone tissue in this part of the carcass side of the M breed led to the fact that 38.90% of total bone weight in four parts of the carcass side was in the back loin part. Contrary to this, of the total bone weight in four parts of the carcass side, 21.61% was shoulder bone tissue, which is 1.94% more than in Moravka. Moravka had more skin and subcutaneous fat tissue on average by 0.968 kg.

Male castrated animals had lower average weight of ham (by 0.665 kg, $P < 0.05$), lower weight of muscle tissue in the ham (by 0.387 kg, $P < 0.01$), and higher share of bone tissue (by 0.54% $P < 0.05$) than female animals.

Carcass side part	Trait	Swallow Belly Mangalitsa	Moravka	Difference
Back loin	Weight, kg	6.545	7.276	0.731**
	Skin and subcutaneous fatty tissue, kg	3.345	3.700	0.355*
	Bone tissue, kg	0.733	0.837	0.104*
	Muscle tissue—share in four carcass side parts, %	21.35	23.53	2.18**
	Bone tissue—share in four carcass side parts, %	35.81	38.90	3.09*
Shoulder	Bone tissue—share in four carcass side parts, %	21.61	19.67	1.94**
Four main carcass side parts	Skin and subcutaneous fatty tissue, kg	10.817	11.785	0.968**

*$P < 0.05$
**$P < 0.01$

Table 11.
Influence of breed on weight variation and tissue share in carcass side parts (only significant differences).

The share of muscle tissue in the ham in the total weight of this tissue in the four main parts of the carcass side was lower (by 2.31%) than in female animals. In the belly rib part of the carcass side, the castrates had less intermuscular fat tissue (by 0.187 g) and bone (by 32 g) than females. The intermuscular fatty tissue in the belly rib carcass part of the castrates made 29.44% of this tissue in four main carcass parts, which is 5.54% less than in females. The bone weight in the belly rib carcass part of the castrates was 11.33% and in females 12.70% of this tissue in four parts of the carcass side. A smaller share of the bone tissue in the castrates of 1.37% is statistically significant. The skin and subcutaneous fatty tissue in the back loin part made 32.82% of these tissues in four parts of the carcass side, which is by 2.81% more than in female animals.

Quantitative indicators of the quality of carcass and meat [27] were examined in fatteners of three genotypes and two Mangalitsa strains (White BM and Swallow Belly strain—LM of Mangalitsa breed) and Swedish Landrace (SL). In total, 36 male castrated animals were examined. Experimental animals were reared in the same facility from 20–25 to 100 kg body weight. Each animal was provided with 5 m^2 of surface. The diet was ad libitum with two complete mixtures. Animals were slaughtered at a body weight of about 100 kg, in the same slaughterhouse. The average slaughter weights of BM, LM, and SL were 100.7, 100.8, and 96.2 kg, respectively. There were no significant differences in slaughter body weight between genotypes. *Musculus longissimus lumborum et thoracis* (MLLT) SL contained more water (72.7%) than BM (64.3%) and LM (62.7%). The share of proteins in MLLT was significantly ($P < 0.001$) higher in SL (22.1%) and SBM (21.1%) fatteners than in LM fatteners (19.5%). Contrary to this, SL fatteners had less fat (4.23%) than BM and LM (13.5 and 16.8%). The established differences were significant at 99%. The content of saturated fatty acids (SFA) in 100 g of MLLT was higher in SL (43.4 mg) than in LM (35.3 mg) and BM animals (33.8 mg). There were no significant differences in the content of SFA between the strains of Mangalitsa. Contrary to this, the content of monounsaturated fatty acids (MUFA) was lower in the MLLT of castrates of the Swedish Landrace (44.9 mg) than LM (55.1 mg) and BM (58.0 mg) strains. The ratios of n-6/n-3 polyunsaturated fatty acid (PUFA) in BM, LM, and SL were 45.63, 14.05, and 34.01%, respectively. The share of cholesterol in MLLT was the lowest in SL fatteners (47.1% versus 62.3 and 62.9%).

Two autochthonous breeds (Swallow Belly Mangalitsa and Moravka) and crosses of these breeds (F1 generation) were reared under the same conditions and fed with mixtures of the same composition [28]. At an average age of 338 days, they had 110.40 kg. In the left carcass side, they had an average of 31.06 ± 3.73% of meat. Meat was of normal quality (pH_1 = 6.35 ± 0.24). The muscle tissue of the ham, shoulders, belly rib, and back loin part was 45.02, 43.26, 29.20, and 25.71%, respectively. Fatteners increased body weight by 329 g/day. The average daily gain in the weight of warm carcass sides was 271 g. The skin and subcutaneous fatty tissue in the four main parts of the carcass side on average showed more intense increase (37 g/day) than the muscle tissue (29 g/day). F1 generation crosses had more intensive body weight gain (352 g), weight of warm carcass sides (295 g), muscle tissue (32 g), and skin and subcutaneous fat tissue weight in four parts of the carcass side (41 g) than the average obtained for the parent breeds. The heterosis effect for calculated daily gain was 8.81, 11.3, 14.3, and 15.5%, respectively. A more intense increase in the weight of skin and subcutaneous fatty tissue is not preferable in four carcass parts of the F1 generation.

7. The fatty acid composition of the long back muscle

7.1 The influence of the housing system, breed, and pig gender

Oils and fats are essential in human nutrition; however, the health condition is negatively affected by too much or too little fat. The World Health Organization [29] reports a link between nutrition and chronic illnesses. In the human nutrition, there should be 15–30% of energy from fat, of which less than 10% should be saturated fatty acids because their higher levels increase the content of cholesterol and triglycerides in the blood. The share of polyunsaturated fatty acids should be 6–10% due to the need for essential fatty acids. Preferably, the *n*-6 and *n*-3 PUFA should be at 5–8% and 1–2%, respectively, but not more than 1% of trans-fatty acids. Most fatty acids are monounsaturated fatty acids (MUFA), primarily oleic acid (C18:1n-9). They are less susceptible to oxidation and have a positive effect on cholesterol levels. Increased intake of *n*-3 fatty acids in relation to *n*-6 has a positive effect on human health [30]. Pig meat is richer in linoleic acid (C18:2, *n*-6), which increases the total content of *n*-6 fatty acids in pork products [31]. The fatty acid composition of the pig fat and muscle tissue is influenced by a number of factors such as genetic factors [32–34], breed [35–38], gender, body weight [39], age, energy intake, fatty acid composition of the diet, and housing system [11, 36, 40, 41].

The results of the experiment [24] showed that the male castrated animals of Mangalitsa breed reared in the free system had more SFA (35.5 versus 33.9%) and *n*-3 PUFA (0.641–0.152%) than the fatteners in the conventional rearing system. The *n*-6/*n*-3 ratio in MLD was higher in fatteners reared in the conventional system than in the free system (37.3–9.2). The cholesterol content was not significantly different in MLD fatteners kept in different systems (61.7–63.1 mg/100 g). Fatteners reared in the free system had more proteins (21.7–19.0%) and less fat (12.1–18.2%) in the MLD than the animals in the conventional system.

The chemical composition [40] of the long back muscle (MLD) was examined in fatteners of Swallow Belly Mangalitsa and Moravka.

Body weight at slaughter of ML and M fatteners was on average 107.14 ± 2.85 and 107.61 ± 3.06 kg, respectively. Also, the slaughter weight of fatteners did not vary between castrates and gilts. A smaller share of water in MLD of Moravka animals meant that there was more total fat (6.96% compared to 5.10%) and the established difference was significant. The male castrated animals of M breed had more fat than gilts of the same breed (8.64–5.29%), and the difference in mean values of 3.35% was statistically significant. Significant differences between the mean values of fat content (5.25–4.94%) were not found between fatteners of different genders of the ML breed. The protein content of MLD of Swallow Belly Mangalitsa was increased by 0.92% compared to Moravka, and this difference was statistically highly significant.

In the study by Migdal et al. [42], no differences between Mangalitsa and Moravka in protein content (20.7–20.2%) were found. Meat proteins, which can be up to 24%, have a high biological value. The water and protein content are in a relatively constant ratio, i.e., there is 3.2–3.7 times more water in meat than protein, as stated by *Vuković* [43]. In our studies, this ratio is 3.2 (breed ML) and 3.3 (breed M). For fatty acid profile, Swallow Belly Mangalitsa was characterized by statistically the highest level of n-6 and n-3 PUFA (7.771 ± 0.728 and 0.416 ± 0.038, respectively), and CLA levels were the highest in Moravka and the lowest in Swallow Belly Mangalitsa (0.079 ± 0.010 and 0.072 ± 0,007, respectively) in the results of the experiment by Migdal et al. [44].

The breed of fatteners influenced the variance of total saturated fatty acids (ΣSFA) in MLD (**Table 12**) [40]. M breeders had an average of 41.64% and fatteners ML 39.45% of SFA. The difference in mean SFA of 2.19% is statistically significant. Both genders of ML fatteners had less saturated fatty acids than M fatteners.

The content of all monounsaturated fatty acids (ΣMUFA) varied under the influence of the breed. ML fatteners had more total monounsaturated fatty acids than M fatteners (56.41–53.78%). The difference in the corrected mean values of MUFA between breeds (2.63%) was statistically significant. Significant variations between male castrated and female animals of the same breed were not found. Male castrates and female animals of Swallow Belly Mangalitsa breed had higher content of MUFA (56.92 and 55.9%) than both genders of the Moravka breed (53.56 and 53.91%). The share of total polyunsaturated fatty acids (ΣPUFA) did not vary under the influence of the breed.

Trait	LS Mean ± SE	
	Mangalitsa	Moravka
ΣSFA	39.45 ± 0.55^a	41.64 ± 0.57^a
ΣMUFA	56.41 ± 0.56^a	53.78 ± 0.58^b
ΣPUFA	4.10 ± 0.30	4.54 ± 0.31
C14:0	1.33 ± 0.03	1.34 ± 0.03
C16:0	25.05 ± 0.32	25.53 ± 0.34
C16:1	4.19 ± 0.14^a	3.70 ± 0.15^a
C17:1	0.34 ± 0.02^a	0.24 ± 0.03^a
C18:0	12.73 ± 0.37^a	14.40 ± 0.39^b
C18:1	50.82 ± 0.48^a	48.51 ± 0.50^b
C18:2	3.92 ± 0.28	4.26 ± 0.29
C18:3	0.21 ± 0.04	0.31 ± 0.04
C20:0	0.23 ± 0.04	0.26 ± 0.05
C20:1	1.07 ± 0.08^a	1.32 ± 0.08^a
P/S[†]	0.10 ± 0.01	0.11 ± 0.01

$^{a-b}P < 0.05$

Table 12.
Influence of fatteners' breed on variation of fat acid composition/profile of musculus longissimus dorsi.

The most common saturated fatty acids in MLD of Mangalitsa and Moravka fatteners were C16:0 (palmitic acid, 25.05 and 25.53%) and C18:0 (stearic, 12.73 and 14.40%). Both fatty acids C14:0 and C20:0 made 4.0 and 3.8% of all SFAs. The breed influenced the variation of the stearic acid content. In MLD of fatteners M, there was by 1.67% more stearic acid than ML.

The most common monounsaturated fatty acid was C18:1 (oleic). Fatteners of Swallow Belly Mangalitsa had more oleic acid than Moravka (M, 50.82 versus 48.51%). The content of C18:1 in MLD did not vary between genders of the same breed. The second common MUFA was C16:1. Significant differences in palmitoleic acid mean values (0.49%) were found between LM and M fatteners. The content of eicosenoic acid in MLD varied between the breeds but did not vary statistically significantly between the genders of the same breed. MLD of M fatteners contained more C20:1 by 0.25%. The variation of the content of C17:1 was influenced by the breed of fatteners, so MLD in Mangalitsa fatteners had more of these fatty acids (by 0.10%) than in the Moravka breed. The most common polyunsaturated fatty acids were C18:2 (linoleic acid) compared to C18:3 (linolenic acid). The contents of C18:2 and C18:3 in MLD did not vary under the influence of breed and gender of fatteners.

If the obtained mean values for fatty acids in MLD of Mangalitsa, Moravka, and meaty breed (SL), the results from our previous research [35] reared under the same conditions, are compared, it can be concluded that ML and M had a lower content of SFA (39.45, 41.64, and 43.76%, respectively), higher content of MUFA (56.41, 53.78, and 41.22%, respectively), and lower content of PUFA (4.10, 4.54, and 14.74%, respectively). Fatteners of SL breed (Swedish Landrace) compared to the ML and M breeds had more total SFAs (4.31 and 2.12%), fewer MUFAs (15.19 and 12.56%), and more PUFAs (10.64 and 10.20%).

Polyunsaturated essential fatty acid (linoleic acid, C18:2 n-6) introduced to the organism through food passes through the digestive tract of the pig unchanged; it is resorbed from the small intestine to the bloodstream and is incorporated into the tissue. Pig meat is richer in linoleic acid content (C18:2, n-6), which increases the total content of *n*-6 fatty acids in pork products [31]. The pig nutrition in the final stage of fattening which includes acorn positively influences the fatty acid composition of the muscle, i.e., the content of oleic acid was higher and the shares of palmitic and stearic acid lower. Also, nutrition ad libitum in the last 3 weeks has affected the share of linoleic acid in MLD, so the *n*-6/*n*-3 fatty acid ratio was three times lower in black Slavonian pigs than in pigs that were fed with complete mixture. There were fewer triglycerides (48%) and cholesterol (by 11%, [45]) in the blood of pigs fed with acorn (ad libitum in the last 3 weeks). Meat of pigs reared in this way is better for processing into traditional meat products but also has better nutritional value for human consumption.

Grazing/pasture is the source of *n*-3 fatty acids. Pig nutrition on pasture leads to the increase in the levels of linoleic and omega-3 fatty acids and reduction in the ratio of omega-6 to omega-3 fatty acids [46].

The ratio between polyunsaturated and saturated fatty acids should be greater than 0.4, but on the other hand, not only the high content of polyunsaturated fatty acids is sufficient, but also the *n*-6/*n*-3 ratio is important. It is recommended that the ratio between PUFA/SFA should be greater than 0.45 and lower than 1.0. In our research, the P/S ratio was not favorable because it was 0.10 (ML) and 0.11 (M).

Meat of two indigenous breeds (Swallow Belly Mangalitsa and Moravka) and meaty breeds was used for the production of Kulen sausage [23, 47]. In all types of Kulen sausage, there was on average 33.75% protein. The protein content in Kulen sausages A and J (made using the meat of Mangalitsa pigs) was 34.62 and 27.18%, respectively. More than 35% protein was in Kulen B (made from meat of meaty breeds, 35.79%), D (made from meat of all three pig breeds, 35.63%), and E (made using the meat of Moravka pigs, 35.04%). The contents of proteins, cholesterol, saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids in Kulen sausage S were 34.42, 66.00, 40.21, 45.79, and 14.00%, respectively. Kulen sausage S (produced from 70% of Mangalitsa meat and 30% Moravka meat) had the highest average mean score for all eight organoleptic properties (5.20 ± 0.49) given by professional assessors. Kulen sausage S had an average ranking of 1.38 ± 0.96 in terms of overall acceptance, which means that professional appraisers and appraisers-consumers had the same choice.

8. Conclusion

In our country, as well as in surrounding countries, autochthonous pig breeds are reared in an open and closed system (farm conditions) and fattened to a different final body weight depending on market demands. On the one hand, the number of animals of Mangalitsa and especially Moravka breed is low, and the production is unorganized. On the other hand, meat products of autochthonous pig breeds have a high price and are available to a small number of consumers.

Potentially endangered indigenous breeds of pigs in Serbia are registered, phenotypically defined, and recorded in appropriate databases. Previous results have shown that there are problems relating to their identification, records, control of production traits, planned mating, coefficient of relation between them, and inbreeding within autochthonous races. For a safer and more justified conservation program, a more accurate, more reliable characterization of pig breeds on the list of protected (Mangalitsa, Moravka, and Resavka) is necessary. Using the method of molecular genetics, the status of authenticity or autochthonousness of pig breeds, which are included in the program of conservation, must be established and carried out with a number of farmers—animal owners.

Preliminary results of the genetic characterization of breeds with MS markers, using two programs (Faculty of Agriculture, University of Osijek), clearly separate animals of Mangalitsa breed from Moravka. They also show that Moravka breed is less uniform and consists of at least two populations. The reason may be the possible crossings that have occurred. Literary data show that there were two types of Moravka. About 91% of the blood samples analyzed (Breeder A) show that these animals belong to Mangalitsa breed. In the herd of the Breeder G, only 54% of the analyzed samples show affiliation with Mangalitsa breed, and 46% have genes of other breed/breeds.

After determining the genetic affiliation of the animal to the endangered breeds, herds are to be formed, which should be permanently protected in order to preserve the specificity of the genetic value. Breeds that are not intended for breeding should be included in commercial programs or organic/ecological production in order to obtain raw materials for the production of traditional products that would have significance in rural development.

In the coming period, the focus in in situ conservation, population increase, and research should be on Resavka breed.

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Author details

Čedomir Radović[1]*, Milica Petrović[2], Marija Gogić[1], Dragan Radojković[2], Vladimir Živković[1], Nenad Stoiljković[1] and Radomir Savić[2]

1 Institute for Animal Husbandry, Belgrade, Republic of Serbia

2 University of Belgrade Faculty of Agriculture, Belgrade, Republic of Serbia

*Address all correspondence to: cedomirradovic.izs@gmail.com

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