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Prospects for Sustainable Production of the Banija Spotted Pig in Relation to Fattening, Carcass, and Meat Quality Traits: A Preliminary Study

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Abstract: The Banija spotted pig (BS) is a Croatian autochthonous breed that was officially recognised in 2018. The breed remains threatened with extinction and is on its way to establishing a production cycle that will ensure long-term conservation and sustainability. However, there is a general lack of data on the production traits of BS pigs. The aim of this work was therefore to identify the main fattening, carcass and meat quality traits of the BS pig and to assess the suitability of the breed for sustainable pork production. A total of ten pigs were fattened in a semi-free-range production system up to the average final body weight of 162 ± 17.3 kg. At the end of fattening, the growth, carcass and meat quality traits (pH, meat colour and water holding capacity) of the BS pig were determined and the gross margin based on the production of value-added meat products was calculated and compared with other Croatian local pig breeds. The results, which are to be considered preliminary due to the small data set, show that the fattening and slaughter characteristics of the BS pig are satisfactory and consistent with the characteristics of the breed and the husbandry practices adapted to semi-free-range farming. Furthermore, the meat quality showed suitability for processing for most traits, while the calculation of gross profit confirms the advantage of this breed for a well-rounded production cycle compared with related local pig breeds.



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1. Introduction

The Banija spotted pig (BS) is a local Croatian breed officially recognised in 2018 and formally registered as the third Croatian autochthonous pig breed, along with Black Slavonian and Turopolje pig breed. The BS breed was developed in the late 19th century by crossing the local Turopolje pig with the Berkshire pig and later with improved Landrace type pigs [1]. The breed was very popular in the Banija (or Banovina) region and parts of Nature Park Lonjsko polje in central Croatia, especially for the homemade processing of meat into dry cured meat products. For this area, the BS pig has an exceptional cultural and historical significance, as, after the Turopolje pig, it formed the basis for the development of the well-known local meat processing industry Gavrilović Ltd. from the end of the 19th century until the beginning of the Second World War [2]. Systematic selection work was carried out on the Božjakovina farm near Zagreb in the middle of the 20th century, but the breed was never fully standardised [2]. According to the description by Šram [3], the BS pig has yellow-grey hair with large irregular black patches on the body, sharp and shiny hair near the body, medium sized floppy ears and a long and deep body. An adult pig weighs between 150 and 200 kg, sows have six–seven pairs of teats and pigs have between eight and 14 piglets. The breed had almost disappeared from this region between the middle and end of the 20th century due to the pressure from highly productive imported breeds and as a result of warfare in the 1990s [4]. For many years, there was no information on the

status of the breed and the number of animals, so Barać et al. [2] placed the BS pig into the group of extinct and insufficiently known breeds.

Nevertheless, in 2013 a national programme was launched to protect and consolidate the remaining BS pig population. The primary objective was to increase the number of purebred animals, but also to determine the breed's main production traits and, in particular, to re-evaluate its potential for producing meat products of exceptional quality, for which it was known in the past. However, these activities were partially slowed after the catastrophic earthquake in 2020 that hit the centre of the BS pig farming area.

Today, the breed is still rare and endangered with a population of about 183 sows and 44 boars [5]. The traditional production system of BS pigs is free range or semi-free range, with the farrowing and piglet rearing phase mainly taking place indoors and the outdoor area being used for sows and fattening pigs, usually from spring to late autumn. Although the revival of the breed was supported by the local authorities and the state in the first phase, the long-term conservation and sustainability of the breed can only be achieved by establishing a production chain that ends with high-quality meat products with added value. Traditionally, there are some recognisable products from BS pigs that are mainly consumed locally, such as sausages and salami, but diversification of the product range and cooperation with the local meat processing facilities are needed to build a production chain. However, there is no information in the literature on current data on the production traits of BS pigs, including information on growth performances, carcass or meat quality traits.

The aim of this work was therefore to identify the main fattening, carcass, and meat quality characteristics of the present population of BS pig, and to evaluate the suitability of BS pigs for more sustainable pork production, including the sale of value-added meat products.

2. Materials and Methods

2.1. Animals and Housing

The study of the production and meat quality characteristics of BS pigs from a semi-outdoor production system was carried out on 10 pigs (6 gilts and 4 barrows) from two litters. As the study was carried out in the initial phase of the breed's revival, the sample size could not be larger due to the small number of available animals. The piglets selected for experiment were born in July 2016 on a local small-scale family farm in Taborište near Petrinja town. The lactation lasted 6 weeks, after which the piglets were moved to nursery facilities. At the end of nursery stage piglets were 4 months old and with average body weight of 31.5 ± 3.6 kg.

The fattening of pigs was carried out in two phases. The first fattening phase lasted from November 2016 to April 2017 (5 months), and the second phase from April 2017 to November 2017 (7 months). The first fattening phase was carried out in an enclosed building (indoor) with a solid floor, and approximately 1.5 m^2 of floor space available for each animal. The second fattening phase in outdoor system started with an average weight of 102 ± 10.5 kg and age about 9 months. At the end of each fattening phase pigs were weighted individually and daily gains were calculated as division between total gain of pigs in the particular fattening phase and number of days.

The outdoor production system covers 1 ha of grassy area surrounded by a wire fence and an electric grazing fence on both sides of the wire fence, as required by the current biosecurity measures. Pigs had free access to shelter to protect them from adverse weather conditions and insulation.

2.2. Nutrition and Diet

At the end of fattening, the average age of the pigs was 16 months and their average final weight obtained at the slaughtering day was 162.2 ± 17.3 kg. Two corn–barley feed mixtures were used. In the first fattening phase, the pigs were fed with complete feed mixture (13 MJ metabolic energy/kg of feed mixture and 16% crude protein) at a level of 1 kg/day at the beginning to 3 kg/day at the end of the first fattening phase. In the second

fattening phase, the pigs were fed by feed mixture (13 MJ metabolic energy/kg of feed mixture and 14% crude protein) at an average amount of 2 kg per pig per day. Additionally, in the outdoor production system, beside nutrients obtained by mixture, pigs had access to a natural source of nutrients from vegetation and soil. In both fattening phases, water was provided 24 h a day.

2.3. Carcass and Meat Quality

The slaughter of the BS pigs was carried out in November 2017 at a local slaughterhouse, approximately 15 km away from the experimental farm. The day before slaughter, the pigs were housed in an enclosed facility on the farm so that loading onto the lorry the next morning could be achieved quickly and with as little stress as possible. The night before slaughter, the pigs were not fed, and water was available to them. The transport of the pigs from the farm to the slaughterhouse took about 30 min, then the pigs were unloaded and taken to the resting pen for about an hour, where they were allowed to settle and rest before slaughter to reduce the possible negative effects of transport and handling on meat quality.

The pigs were stunned with an electric current using head-only stunning electrodes, bled, scalded for 5 to 10 min in water heated to 60 to 70 °C and then peeled. The hair that could not be removed by hand was burned with a gas burner. In addition to the hair, the corners of the paws, the ear canals and the eyeballs were removed, and then the organs of the pelvic, abdominal and thoracic cavities were eviscerated. After evisceration, the carcasses were cut in half and samples of the diaphragm were taken for *Trichinella spiralis* analysis. The carcasses were then weighed to determine the weight of the warm carcass and then chilled at 4 °C for 24 h. Additionally, the carcass length was measured one hour after slaughter as the distance from the cranial edge of *os pubis* to the cranial edge of the first rib, as well as measures of muscle (M) and backfat thickness (F) used for calculation of lean meat percentage (%). Lean meat percentage, muscle thickness (M), and fat thickness (F) were determined by the “Two-point (ZP)” method approved in Croatia [6].

The day after the slaughter, the left halves were cut into the main parts of the carcass. Some of these, such as the ham, neck and bacon, were processed for drying and the production of dry-cured products. Other meat and fat tissues were used to make sausages, lard and greaves. After all the products had been made ready for consumption, they were weighed, and the gross margin was calculated based on these values and the average prices for the respective product. The calculation was undertaken according to the average weight of the carcasses, and comparison made with other local pig breeds was using information from a previous analysis of two other Croatian local breeds: Turopolje, and Black Slavonian pig [7].

To study the meat quality, measurements of the pH of the meat, measurements of meat colour and water holding capacity were carried out. The measurement of the pH of the meat was undertaken in two phases by inserting the probe of a digital pH metre (TESTO 230, Germany) in the right halves of the carcasses. The first measurement was taken 45 min (pH₄₅) after slaughter (*postmortem*) with the temperature of the carcasses close to body temperature, while the second measurement was taken 24 h *postmortem* which time the carcasses had been placed in cold storage and their temperature was about 4 °C. In the first measurement, the pH₄₅ of the *m. longissimus dorsi* (MLD) at the level of the eighth rib was measured, and in the second measurement, the pH₂₄ of the MLD, and two muscles on the fresh ham—the *m. semimembranous* (MS) and the *m. gracilis* (MG)—were measured.

The colour of the meat was determined by using a Minolta Chromameter CR-410 device, which measures CIE LAB parameters [8] of meat colour expressed as L* (lightness), a* (redness/greenness), and b* (yellowness/blueness) values. The L* value refers to paleness (value from 0–100), a* to the degree of redness of the meat, i.e., the spectrum from green to red colour (value from –60 to 60) and b* to the degree of yellow colour, i.e., the spectrum from yellow to blue (value from –60 to 60). The meat colour was determined

24-h *postmortem* on a fresh cut surface of the abovementioned muscles after 5 min of blooming time.

The drip loss was determined by using the EZ-DripLoss method [9]. Muscle samples for the drip loss determination were taken from the cranial edge of the long back muscle (*m. longissimus dorsi*) of each carcass between the 13th and 14th ribs at 24 h *postmortem*. The muscle samples were taken using a standard stainless-steel probe following the vertical fibre orientation and with a 2.5-cm diameter. The muscle samples were taken in duplicate in the dorsal position. Each muscle sample was placed in a special pre-weighed specialized EZ container (Danish Meat Research Institute, Taastrup, Denmark), and stored in a refrigerator at a temperature of +4 °C. After the measurement interval of 24 h and 48 h, each container was weighed while including muscle sample and drip loss, and then again, after removing muscle sample, to weigh just the drip loss. Dabbing prior to weighing was not performed as the weight of the sample was not considered in the determination of drip loss. The EZ-DripLoss assessment was performed according to DMRI [10]:

$$\text{EZ - Driploss} = [(W_I - W_c) / (W_t - W_c)] * 100$$

where:

W_c = weight of the empty EZ-DripLoss container

W_t = weight of the EZ-DripLoss container with meat sample and drip loss, and

W_I = weight of the EZ-DripLoss container with drip loss.

As introduced by Rasmussen and Andersson [9], the mean value of muscle samples taken in duplicate was used for each EZ-DripLoss assessment.

2.4. Economics of Animal Husbandry

Economics of pig production for three Croatian local breeds reared in similar production systems were based on results obtained by Lukovic et al. [7]. The profit in production of fattening pigs was calculated as the difference between total income and total expense. The total income was based on the sale of the main meat products (dry ham, dry cured bacon, salami, dry cured neck, greaves, and lard) with average prices valid for the Croatian market. The total expense was calculated as the cost of feed increased by other production costs, with the assumption that feed costs account for 70% of the total production costs. The calculation of profit was based on an average daily feed consumption of 2 kg and an average feed price for fattening pigs of 0.30 €/kg. Pigs were fattened for a total of approximately 400 days' \times 2 kg/day feed mixture = 800 kg feed mixture \times 0.30 €/kg = 240 €. Assuming that feed costs account for 70% of the total production costs, the total production costs = 240 € \times 100/70 = 343 €.

2.5. Statistical Analysis

Statistical analysis included basic statistics (mean value, standard deviation, minimum and maximum value, and coefficient of variation) for traits observed using PROC MEANS of statistical package SAS 9.4 (SAS Institute, Cary, NC, USA).

3. Results and Discussion

3.1. Fattening Traits

The descriptive statistics for the fattening characteristics of 10 BS pigs are presented in Table 1. The pigs started fattening with an average initial body weight of 31.5 ± 3.6 kg, ranging from 25 to 39 kg. After the lactation and rearing phase, the pigs started the first fattening phase in the pen at about four months of age. The final body weight of the pigs at the end of fattening at 16 months of age ranged from 145 to 196 kg, with an average final body weight of 162.2 ± 17.3 kg. The average daily gain in the first fattening phase indoors was almost 200 g higher than the daily gain in the second fattening phase outdoors (474 ± 34.2 g vs. 286 ± 67.9 g).

Table 1. Fattening traits of the Banija spotted pig.

Trait	Mean	SD	Min	Max	CV, %
Initial body weight, kg	31.5	3.6	25	39	11.4
Final body weight, kg	162.2	17.3	145	196	10.7
Daily gain (indoor), g	474	34.2	402	524	7.2
Daily gain (outdoor), g	286	67.9	196	354	23.7
Total daily gain, g	363	25.3	323	394	7.0

The coefficients of variation for initial and final body weight were at similar levels (11.4% vs. 10.7%). The variation of daily gains in the second fattening phase outdoors is considerably larger compared with daily gains in the first fattening phase indoors (23.7% vs. 7.2%). Due to the restrictive feeding regime during the second fattening phase, when the pigs received on average only 2 kg feed per day, the variability of the initial body weight could be a possible reason for the high variability of daily gains. As part of the nutrient requirement that was covered by natural sources outdoors, there are of course also individual differences between the animals in terms of their adaptability to the new environment.

The reduction in daily gains in outdoor production systems is probably due to movement [11,12] and climatic conditions [13], although Dostalova et al. [14] found no difference in daily gains between Prestice Black-Pied pigs kept indoors and outdoors. Regarding climate, the continental part of Croatia often experiences suboptimal temperatures (frost) in early spring and late autumn, which can drastically reduce growth traits. The total daily gain during the entire fattening period in BS pigs is 363 g, which seems very low compared with modern pig breeds. However, in the production of local pig breeds, meat quality is more important than fast growth, and the extension of the fattening period is commonly used to obtain meat that is more suitable for processing into high-quality meat products [7].

Although the daily gain of pigs depends mainly on genotype and feeding, the growth characteristics of the BS pig are comparable to those of other European autochthonous pig breeds, in which a lower growth rate was observed during late fattening or both early and late fattening [15]. Senčić and Samac [16] determined an average daily gain of 645 g in Black Slavonian pigs weighing 30 to 130 kg, kept in a semi-free-range system and fed with complete feed mixtures. On the other hand, Black Slavonian fattening pigs fed a combination of feed mixtures and lucerne had a lower daily gain (520 g), which is more comparable to that of BS pigs.

According to Đikić et al. [17], fattening pigs of the Turopolje breed achieved a daily gain of 400 to 500 g in intensive fattening from 20 to 100 kg. The achieved daily gains are quite high for the Turopolje breed and comparable to the daily gains of BS pigs in the first indoor fattening phase. However, compared with the daily gains achieved in the second fattening phase of the BS fatteners, these daily gains were higher. Đikić et al. [18] also found that Turopolje pigs kept in a free-range forest system grew very slowly. They reported that the average fattening period of Turopolje pigs was 584 ± 20 days. The final body weight before slaughter was only 81.9 ± 6.1 kg. In a more recent study, Karolyi et al. [19] also found slow growth of the Turopolje pig in traditional free-range conditions, with an average daily gain of 392 g during the fattening period and a final age and weight of 552 days and 95 kg, respectively. Compared with our study, a higher final body weight was achieved with the BS pig. The long fattening period of all local Croatian pig breeds is part of the traditional low-input production system, where fatteners are raised to a higher final age and weight and taken to the slaughterhouse usually in November, when the climate is more suitable for meat processing and preservation.

3.2. Carcass Traits

Carcass traits of BS pigs are shown in Table 2. Heavy BS pigs had a warm carcass weight of 133.7 ± 16.3 kg, and a warm dressing percentage of 82.3% (Table 2). The average carcass length was 88 cm.

Table 2. Carcass traits of the Banija spotted pig.

Trait	Mean	SD	Min	Max	CV, %
Warm carcass weight, kg	133.7	16.3	115.4	165.4	12.1
Warm dressing percentage, %	82.3	1.9	79.5	84.3	2.3
Carcass length, cm	88.2	5.7	80	97	6.5
Backfat thickness (F), mm	35.3	7.2	26	52	20.4
Muscle thickness (M), mm	62.4	5.7	52	70	9.1
Lean meat percentage, %	45.1	4.5	37.0	48.8	10.1

Butko et al. [20] have reported that Black Slavonian pigs in an outdoor system need around 180 days more than in an indoor system to reach a final weight of 135 kg (540 days vs. 359 days). In both production systems Black Slavonian pigs had similar dressing percentages as BS pigs in our study. According to Senčić et al. [16], Black Slavonian pigs had a much lower final weight and consequently a lower carcass weight compared with BS pigs. There were also differences in carcass characteristics between pigs with respect to feeding intensity. Pigs consuming only feed mixture had a higher cold carcass weight compared with pigs fed a combination of feed mixture and lucerne (53.0 kg vs. 52.7 kg). Luković et al. [7] found that Black Slavonian fattening pigs achieved almost 30 kg less slaughter weight compared with BS pigs of the same age. Similar results for free-range Black Slavonian pigs were found by Baković [21], where pigs reached a final weight of 130–140 kg at 18 months of age.

Backfat thickness (F), measured at the point where *m. gluteus medius* extends into the backfat deepest, was 35 mm, and loin muscle thickness (M) from the cranial edge of *m. gluteus medius* to the edge of the vertebral canal was 62 mm (Table 2). These two measurements were used to calculate the lean meat percentage of the carcasses. With an average lean meat percentage of 45%, the BS pig can be classified in the group of combined pig genotypes for meat and fat production.

In Turopolje pig [22], the average age of the pigs before slaughter was 18 months. The slaughter weight of the cold carcasses of the Turopolje pigs averaged 73.4 kg, and the cold dressing percentage was 77.2%. Similar to this, Đikić et al. [23] noted that Turopolje pigs with a final weight of 100 kg had a warm carcass weight of 80 kg. Further, Đikić et al. [23] also found that Turopolje pigs with a final weight of 100 kg had backfat thicknesses of 32 mm and muscle depths of 50 mm. The results obtained in this study on BS pigs are slightly higher for both traits, though caution should be taken due to the differences in final weight.

It is obvious that BS pigs had higher meat percentages at higher weights than Turopolje pigs. According to the old classification of breeds, the Turopolje pig is a primitive breed, while the BS pig is more intermediate between combined (meat and fat type) and modern meaty breeds. On the other hand, according to Luković et al. [7], the growth of the muscle tissue of Black Slavonian pigs ends at a weight of about 130 kg, and feed conversion increases drastically after this weight if fattened for a longer period.

3.3. Meat Quality Traits

Meat quality traits are a key factor in processing pork into high quality meat products, with pork from local, slow growing breeds and traditional production systems often considered more suitable for processing [24]. Therefore, the three most important meat quality characteristics of BS pigs (pH value, meat colour on the surface of three different muscles and water holding capacity) were objectively measured and presented. The analysed meat quality traits are interrelated and, although they are presented separately, it is necessary to consider them all together for their correct interpretation [25].

3.3.1. pH Value

The rate and the of extent of *postmortem* pH fall affects the water holding capacity and the colour of pork [26,27]. The value of pH₄₅ obtained 45 min after slaughtering in *m. longissimus dorsi* was 6.32 with a range between 6.20 and 6.43 (Table 3).

Table 3. pH values measured in different muscles of Banija spotted pig.

Trait ¹	Mean	SD	Min	Max	CV, %
pH ₄₅ (MLD)	6.32	0.07	6.20	6.43	1.17
pH ₂₄ (MLD)	5.49	0.04	5.44	5.55	0.80
pH ₂₄ (MS)	5.46	0.04	5.38	5.50	0.66
pH ₂₄ (MG)	5.56	0.05	5.47	5.61	0.85

¹ MLD (*m. longissimus dorsi*), MS (*m. semimembranosus*), MG (*m. gracilis*).

Values of pH₂₄ were obtained the day after slaughtering after the cutting of the main carcass parts. Values of pH₂₄ were lower than pH₄₅, as expected. Further, values of pH₂₄ were similar among all three observed muscles. Regarding the variability of pH values, all measurements generally showed a high degree of homogeneity, with a slightly wider range of pH₄₅ compared with pH₂₄.

The mean value of pH₄₅ in the *m. longissimus dorsi* shows that the meat of BS pigs has a normal initial pH decline *postmortem*, and that the meat does not have the characteristics of pale, soft and exudative (PSE) meat, usually indicated by the pH₄₅ values < 6.0 in the halothane positive pigs [28]. The mean values of pH₂₄ were 5.49 ± 0.04 for *m. longissimus dorsi*, 5.46 ± 0.04 for *m. semimembranosus* and 5.56 ± 0.05 for *m. gracilis*, indicating that the meat of the BS pigs does not have the characteristics of dark, firm and dry (DFD) meat—a result of poor pre-slaughtering handling [29]—and that it is of normal quality.

Butko et al. [20] determined pH₄₅ in the *m. longissimus dorsi* in Black Slavonian pigs to be between 6.6 (indoors) and 6.7 (outdoors), which are slightly higher values than in BS pigs. Karolyi et al. [30] found that pH₄₅ in the *m. longissimus dorsi* of Black Slavonian pigs has normal values (>6.0). Furthermore, they reported normal pH₂₄ values (between 5.4 and 6.0) and that the meat of Black Slavonian pigs is suitable for processing into dry cured products, which could also apply to the present results on BS pigs. The results for pH₂₄ obtained in the present study are also in agreement with investigations performed on other local pig breeds from similar rearing conditions, e.g., on the longissimus and semimembranosus muscles of Swallow-Belly Mangalitsa [31] or the longissimus muscle of Krškopolje pigs [32]. In a recent study on the Turopolje pig, Karolyi et al. [19] reported that pH levels of the meat were generally normal, but in some cases the levels for pH₂₄ were close to the limits for acceptable pork quality. This was explained by the effects of the treatment of the animals before slaughter (e.g., handling, loading, and transport), which is usually more demanding in free-range systems.

3.3.2. Meat Colour

From the consumer's point of view, the colour of the meat is the first choice among meat quality characteristics. Meat colour is primarily determined by the content and the chemical state of the myoglobin, the concentration of which increases in pig muscles with ageing [33]. The results of instrumental colour measurements for lightness, redness and yellowness (L*, a* and b* values, respectively) in three muscles of BS pigs are shown in Table 4. The highest values of L* and b* parameters were found in *m. longissimus dorsi*, the lowest L* and b* values were found in *m. gracilis* and *m. semimembranosus*, respectively, while the a* parameter values increased in order MLD < MS < MG. Considering the threshold value of L* = 53 as the highest acceptable L* value for the colour of the most representative longissimus muscle [34], the observed mean L* values in different muscles of BS pigs were lower and thus of suitable quality.

Senčić et al. [35] have reported, in their study on the quality of meat from Black Slavonian pigs reared in a semi outdoor system, a value for the L* parameter of colour in the

longissimus muscle of 51.15 ± 2.41 , and a value for the a^* parameter of 18.43 ± 1.22 , which are in line with values obtained in BS pigs. Senčić et al. [16] compared the meat colour of the Black Slavonian pig and the Swedish Landrace and found that the Black Slavonian pig had a darker meat colour in comparison with the Swedish Landrace ($L^* = 61.25$), which could also apply to the present results on BS pigs.

Table 4. Meat colour measured in different muscles of Banija spotted pig.

Muscle ¹	Trait	Mean	SD	Min	Max	CV, %
MLD	L^*	51.25	2.43	48.88	56.21	4.73
	a^*	19.27	1.57	16.25	20.45	8.13
	b^*	6.69	0.45	5.99	6.92	6.77
MS	L^*	47.05	3.52	42.83	53.68	7.49
	a^*	21.82	0.76	20.77	22.84	3.47
	b^*	5.94	0.94	5.03	6.84	15.89
MG	L^*	39.84	1.57	37.76	42.72	3.95
	a^*	23.68	1.18	21.82	25.95	5.00
	b^*	6.61	0.74	5.88	7.76	11.20

¹ MLD (*m. longissimus dorsi*), MS (*m. semimembranosus*), MG (*m. gracilis*).

Similar observations were made by Karolyi et al. [30] who presented data on the colour of the longissimus muscle of Black Slavonian pigs and crossbred white pigs (Landrace and Large White crosses). They reported mean values for the parameter L^* of 49.93 ± 1.19 for the Black Slavonian pig and 56.08 ± 1.19 for the white pigs, with a^* values of 20.02 ± 0.42 and 18.22 ± 0.42 , and b^* values of 4.67 ± 0.44 and 5.75 ± 0.44 , respectively.

Comparing these results, the meat colour parameters L^* and a^* measured on the *m. longissimus dorsi* in BS pig are in line with values obtained in Black Slavonian pigs, while white pig crossbreeds had paler and less red meat.

On the other hand, the Turopolje pigs showed the darkest *longissimus dorsi* meat colour ($L^* 44.6$), which could be due to slower growth and a more extensive production system compared with other local pig breeds [19].

Nevertheless, the darker and more reddish colour of the meat seems to be one of the most prominent features of the meat of local breeds, as is also reported for the Cinta Senese [36] and Mangalitsa [31] pigs, while BS pigs also show similar characteristics in this respect.

3.3.3. Drip Loss

Drip loss measures the fluid, consisting mainly of water and proteins, that exits a piece of meat within a certain period of time without any mechanical force other than gravity [26]. The mechanisms underlying water retention in post-rigorous meat are complex and not yet fully understood. However, it is known that the rate and extent of pH drop *postmortem*, as well as the structure of the muscle, are the key factors determining the water holding capacity of the meat and thus drip loss [27]. Kaufmann et al. [37] and Warner et al. [38] state that meat with a drip loss value < of 5% is of normal quality and meats whose values exceed this threshold are classified as pale, soft and exudative (PSE) meat. Unfavourable drip loss causes major problems in the pork industry due to its negative impact on the appearance of meat and the yield in further processing [25]. The mean value of drip loss of BS pig in *m. longissimus dorsi* by EZ method was above 5% (Table 5).

Table 5. Drip loss in *m. longissimus dorsi* of Banija spotted pig.

Trait	Mean	SD	Min	Max	CV, %
Drip loss EZ24 ¹ , %	5.76	2.18	2.66	10.75	37.79
Drip loss EZ48 ² , %	7.02	1.94	4.18	11.89	27.59

¹ drip loss after 24 h storage; ² drip loss after 48 h storage.

On the other hand, the pH₄₅ values showed that no PSE meat was present, so that such a high drip loss is surprising. Nevertheless, the observed ultimate mean pH of MLD was 5.49 (Table 3), which is very close to the isoelectric point of major muscle proteins (pH = 5.3–5.4), where electrostatic forces between myofilaments are maximally reduced and proteins lose their ability to attract and bind water [27]. This could be at least a partial explanation for this result. In agreement with our results, Tomažin et al. [32] observed similarly high EZ24 drip losses in the longissimus muscle of Slovenian Krškopolje pigs kept outdoors when the final pH was in a similar range as in the present study. However, Žilić et al. [39] found that drip loss in *m. longissimus dorsi* in Turopolje pig after 24 h in cold storage averaged only $1.40 \pm 0.18\%$, with the range between 0.65% and 3.39%. Furthermore, the mean value of drip loss after 48 h in cold storage was $1.94 \pm 0.23\%$, with the range between 0.98% and 4.98%. These results were much lower than observed in BS pig.

The very high coefficients of variation for drip loss for the BS pigs gave us reason for caution. Borchers et al. [40] have indicated that drip loss is affected by several ante- and postmortem factors. Unfavourable conditions before slaughter (e.g., transport, different environment) or incorrect treatment after slaughter (e.g., chilling) could affect meat quality characteristics. Postmortem factors, such as manipulation of the meat during sampling and transport of the samples to the laboratory were mentioned as possible causes for the high variability of the drip loss values [39].

Senčić et al. [35] found that the meat of the Black Slavonian pig reared in a semi outdoor system lost $4.65 \pm 1.64\%$ of meat juice. In this study, the water-holding capacity was determined by filter-paper press method according to Grau and Hamm [41]. Comparing the average values obtained for all three Croatian local pig breeds, the BS pig had the greatest drip loss ($5.76 \pm 2.18\%$) within the first 24 h. Even after 48 h, the difference in drip loss between BS pig and Turopolje pig was high ($7.02 \pm 1.94\%$ vs $1.94 \pm 0.23\%$).

Correa et al. [42] conducted a study on water-holding capacity using the EZ method on crossbred Duroc \times (Landrace \times Large White) barrows. They found that the mean value of drip loss after 24 h storage was 3.54%. When comparing the results of drip loss after 24 h storage, BS pig showed higher drip loss ($5.76 \pm 2.18\%$) than crossbreeds Duroc \times (Landrace \times Large White). As the above results were obtained using the same method and the meat of BS pigs did not show the characteristic development of PSE meat, it would be necessary to additionally investigate and eliminate the possible causes for these inconsistencies.

3.4. Gross Margin Calculation

The practical way to prove sustainable production of the BS pig is through the potential for making a profit. By comparing three local Croatian breeds of pigs based on the quantities of certain meat products and the possibility of selling them at a certain price, the possibility of preserving and further developing the BS pig is made visible (Table 6).

Table 6. Calculation and comparison of profit in production of three Croatian local pig breeds.

Item	Avg Price €/kg	Pig Breed		
		Turopolje	Black Slavonian	Banija Spotted
Final weight, kg		110	125	162
Slaughter weight, kg		88	104	130
Dry ham, kg	26.00	10	12	16
Dry cured bacon, kg	13.00	8	12	14
Salami, kg	20.00	6	8	10
Dry cured neck, kg	16.00	2	3	5
Lard, kg	1.50	15	20	30
Greaves, kg	13.00	1.5	2	2
Total income, €		558	732	949
Total expense, €		343	343	343
Profit, €		215	389	606

Regardless of the changes in animal feed, live pigs, and meat products prices, the production of BS pigs can be economically efficient and sustainable. Based on the final weight of pigs of a similar age, it is evident that BS pigs—due to their good growth capacity—had the potential to produce more quality meat and meat products in relation to other Croatian local pig breeds (Table 6). The additional profit generated by the sale of value-added meat products allows for the long-term planning of pig production and the possibility to increase pig numbers. Sustainable pig production from local BS pigs could make it possible to retain the population in rural areas and develop these areas. This is particularly important for regions that have been depopulated in recent decades due to various natural or non-natural disasters (earthquakes, war, etc.).

Besides the positive economic calculation based on production of high-quality meat products, Kralik et al. [43] have reported other advantages in the context of profitability of production of local pig breeds in comparison with highly productive hybrid lines. Some of the advantages of the production of local pig breeds in outdoor or semi-outdoor systems reported by Kralik et al. [43] are lesser building costs per sow, the number of sow farrowing, the total piglets produced per sow, the lower replacement rate, the favourable effect on the environment, and the improved welfare of animals.

4. Conclusions

The obtained results indicate that the fattening and slaughtering characteristics of BS pigs are consistent with the characteristics of the breed and the husbandry practice adapted to semi-free-range systems. Compared with some other autochthonous breeds, the BS pig showed more favourable growth and carcass traits, though the results should only be considered preliminary due to the small sample size in our experiment. In addition, the meat quality, studied here based on pH, colour, and water holding capacity, also indicated good suitability for processing, although caution is required, especially with regard to the observed drip losses which need further clarification. Finally, the calculation of gross profit confirms the advantage of this breed for a well-rounded production cycle. Altogether, these preliminary results of fattening, carcass and meat quality traits favour the reuse of this breed as a raw material base for the local meat processing industry and the butchery. Through the production of high-quality meat products and their marketing, the continued existence of the BS breed can be secured in the long term, so that it may once again become the basis for traditional and sustainable pig production in the Banovina region and surrounding areas.

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