



QUALITY AND PROCESSABILITY OF MEAT IN POLISH NATIVE PIGS – A REVIEW*

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Abstract

The primary aim of pig breeding efforts is to produce animals characterized by outstanding performance, including also fattening and slaughter performance traits. However, improved carcass leanness and reduced carcass fatness, especially intramuscular fat content, have led to a deterioration of pork quality and processability. Due to the growing frequency of meat defects and the limited potential use of such meat in the production of premium products this constitutes a considerable problem for the meat industry. The breeds superior in terms of meat quality are native pig breeds, such as those kept in Poland, i.e. Pulawska (Pul), Złotnicka Spotted (ZS) and Złotnicka White (ZW) pigs. The aim of this paper is to present a review of research results concerning quality and processability of meat produced by the Polish native pig breeds. The presented results indicate that pigs of local breeds exhibit a low level of performance traits (daily gain, carcass leanness, backfat thickness) while maintaining very good parameters of meat quality and processability (muscle composition and physical properties, fatty acids profile, sensory traits). Thus, they are used as a source material for premium products. In view of the small size of local populations and higher production costs in Poland it is a niche production. Therefore, the current aim of breeding indigenous breeds is both to maintain a safe population size and genetic diversity and to increase popularity of their meat and processed meat products among consumers. This objective is attained, among other things, thanks to efforts to reduce cost of their production through optimization of environmental conditions and wider use of less expensive traditional feed formulations, which make it possible to fully utilize the potential of local pork resources.

Key words: pig, native breeds, Złotnicka Spotted breed, Złotnicka White breed, Pulawska breed, meat quality

Meat is an essential element of human diet thanks to its chemical composition, nutritive value and the content of quality protein (Biesalski, 2005; Blicharski et al., 2013). In the period of 2019–2021 the mean consumption of pork worldwide was 11.11 kg per capita. According to OECD/FAO forecasts in 2030 it will be 11.75 kg (OECD/FAO, 2023). In Poland, despite the reduction in the pig population size observed for well over a decade, pork consumption remains stable. In 2010 a statistical Pole consumed 42.2 kg of this meat annually, while in 2020 it was 43.4 kg, which indicates continuous consumer interest in pork (GUS, 2022). This in turn shows that eating quality and processability of pork is of current importance.

Over the last few years worldwide the primary aim of breeding work on pigs has been to improve growth and slaughter performance traits (Kušec et al., 2022). In breeding programs the daily body weight gain and meat percentage in the carcass have been used to calculate the selection index whose value determines the suitability of an animal for breeding. When analyzing data covering the last few years and concerning performance testing of breeding material of two popular pig breeds kept in Po-

land, i.e. Polish Landrace (PL) and Polish Large White (PLW), a steady improvement of growth and slaughter performance in both males and females can be observed. In 2010, the mean daily body weight gain in the PL and PLW for young boars was less than 700 g, while carcass leanness was less than 60%. In turn, in 2022, for males daily gains increased to 741 g for PL and 765 g for PLW, and carcass leanness amounted to 60.5% – PL and 61.7% – PLW (PZHiPTCh “POLSUS”, 2011, 2023).

Improvement of fattening and slaughter performance observed in breeding herds results in improved productivity in commercial herds. For example, in the 1980s in Poland the mean carcass leanness in the general population was approximately 47%, while in 2014 it increased to 56.9% (Borzuta and Lisiak, 2016). As shown by data presented by the Ministry of Agriculture and Rural Development, in 2022 it was even higher and ranged from 58 to 59%, with fatteners exhibiting carcass leanness over 60.0% accounting for 40.1% of the annual pig slaughter structure (Ministry of Agriculture and Rural Development, 2023). However, an increase in carcass leanness and reduction of carcass fatness, including intramuscular fat content, has resulted in a deterioration of quality

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traits and processability of pork. This poses a serious problem for the meat industry. At present several defects are reported in meat: excessive exudation or dryness, too pale or too dark color, and inappropriate pH (Blicharski et al., 2013; Tarczyński et al., 2018; Sieczkowska et al., 2019). According to various authors, the share of exudative meat is 68–71%, while acid meat accounts for more than 25% of the raw material (Tarczyński et al., 2018; Sieczkowska et al., 2019).

Studies indicate that individual breeds and lines of pigs differ from one another not only in terms of fattening and slaughter performance traits, but also in broadly understood meat quality (Čandek-Potokar et al., 2019; Radko et al., 2023). Previous research has shown that many native pig breeds are characterized by low fattening and slaughtering characteristics. However, they are distinguished by high-quality meat (Franci and Pugliese, 2007; Ruy et al., 2008; Cebulska et al., 2018).

The aim of this paper is to present a review of research results concerning quality and processability of meat produced by Polish native pig breeds. Meat coming from local

pig breeds is renowned worldwide for its high quality, and thus it is processed into premium products. Examples in this respect include Jinhua ham from China, Iberian ham from Spain, Parma ham from Italy and Barrancos from Portugal (Kosmatko and Węglarz, 2018; Mazzocchi et al., 2022; Hu et al., 2023). In Poland, meat and processed products from native pig breeds are not yet widespread. Currently, a few products are commercially available. Among them are roast legs of the Złotnicka White, white sausages in a jar of Złotnicka Spotted, and traditional cold cuts of Puławska pigs (Ministry of Agriculture and Rural Development, 2006; Radko et al., 2023).

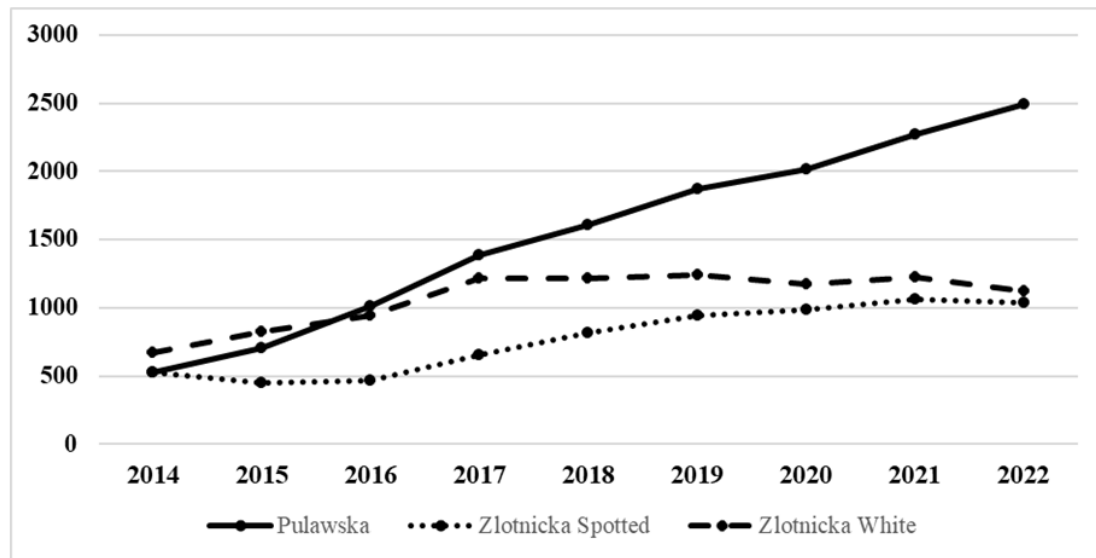
General characteristic of native breeds

In countries of Europe native pigs, with a few exceptions, are not popular and their populations are small in size (Table 1). Many breeds, which were still kept in the last decades of the 20th century, are currently considered to be extinct. Examples in this respect include Sumadja (Šumadinka) in Serbia, Strei and Stocli in Romania, or Shishka (Šiška) in Bosnia and Herzegovina (FAO, DAD-IS, 2023).

Table 1. Native breeds of pigs in countries of Europe

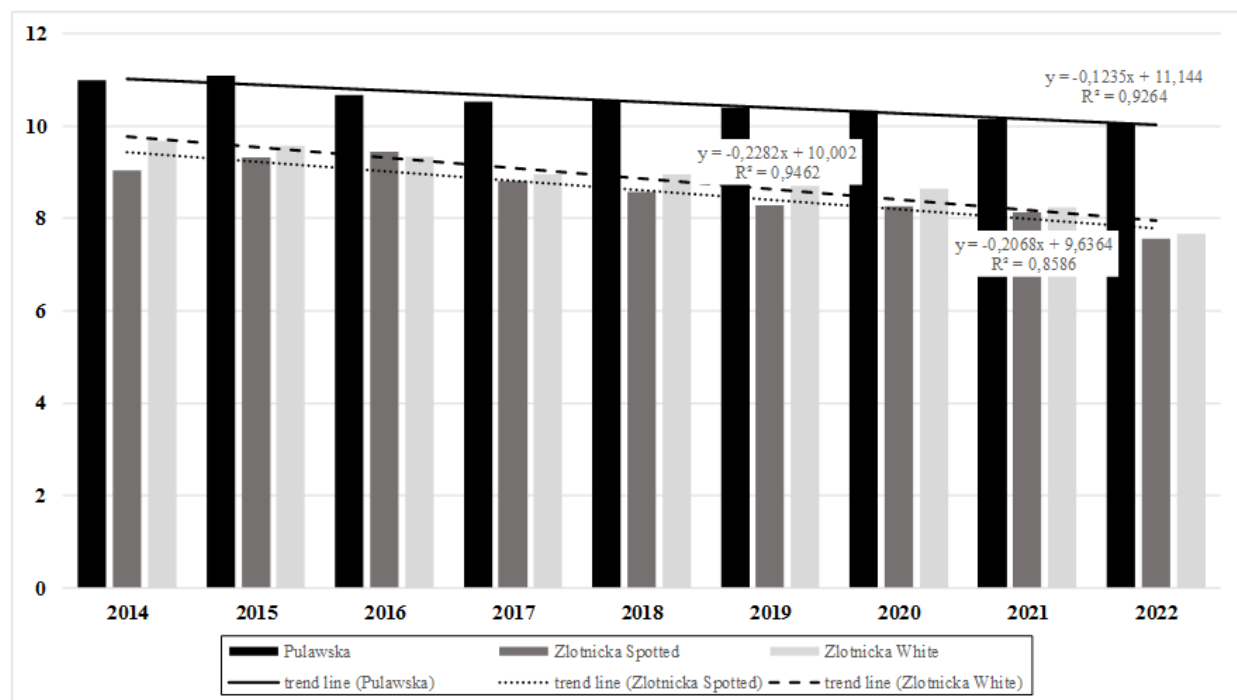
Year	National name / English name	Country	Number of breeding males/females
2021	Iztocnobalkanska svinja / East Balkan	Bulgaria	11 / 115
2022	Fajferica / Black Slavonian pig	Croatia	131 / 2143
2021	Turopoljska svinja / Turpolje pig		18 / 240
2021	Banijska šara svinja / Banija Spotted pig		44 / 183
2018	Přeštice prase / Prestice Black-Pied	Czechia	82 / 500
2014	Porc de Bayeux / Bayeux pig	France	10 / 50
2014	Blanc de l'Ouest / Normand pig		10 / 48
2014	Cul Noir Limousine / Limousine pig		10 / 85
2014	Gasconne / Gascon pig		100 / 826
2014	Nustrale / Corsican pig		100 / 272
2001	Pie Noir du Pays Basque / Basque pig		59 / 306
2021	Szőke mangalica / Blond Mangalitsa	Hungary	53 / 3332
2019	Fekete mangalica / Black Mangalitsa		59 / 222
2019	Fecskehasú mangalica / Swallow Bellied Mangalitsa		45 / 907
2021	Vörös mangalica / Red Mangalitsa		39 / 1503
2022	Calabrese / Calabrese pig	Italy	107 / 704
2022	Casertana / Casertana pig		44 / 212
2022	Cinta Senese / Cinta Senese pig		120 / 692
2022	Mora Romagnola / Mora Romagnola pig		54 / 259
2022	Nero di Parma / Parma pig		12 / 89
2022	Nero dei Nebrodi / Nero Siciliano pig		109 / 698
2022	Suino Sardo / Sarda pig		34 / 134
2021	Lietuvos vietinė / Native Lithuanian pig	Lithuania	19 / 144
2021	Złotnicka pstra / Złotnicka Spotted	Poland	31 / 861
2021	Złotnicka biała / Złotnicka White		46 / 903
2021	Puławska / Puławska		159 / 2260
2020	Bisaro / Bisaro pig	Portugal	496 / 6095
2020	Malhado de Alcobaça		12 / 211
2020	Alentejana / Alentejana pig		462 / 6582
2021	Moravka / Moravka pig	Serbia	169 / 2899
2021	Krškopoljski prašič / Krškopolje pig	Slovenia	84 / 433
2021	Ibérico / Iberian Black	Spain	8553 / 577568
2021	Porco Celta / Celta pig		150 / 704
2021	Ukrainska stepova rjaba i bila svinja / Ukrainian Steppe Black and White pig	Ukraine	4 / 15
2017	Mirgorodska svinja / Mirgorod pig		10 / 150

Source: <http://www.fao.org/dad-is/browse-by-country-and-species/en/> (FAO, DAD-IS, 2023).



Source: <http://www.bioroznorodnosc.izoo.krakow.pl/bazy/stats/swinie>.

Figure 1. Number of Polish native pig breeds in 2014–2022



Source: <http://www.bioroznorodnosc.izoo.krakow.pl/bazy/stats/swinie>.

Figure 2. The mean number of piglets born alive per litter of Polish native pig breeds in 2014–2022

In Poland, similarly to other European countries, to preserve extant populations of native breeds – Pulawska, Zlotnicka Spotted and Zlotnicka White, they have been covered by programs protecting genetic resources. Thanks to such programs the population size is maintained at a relatively safe level, while in recent years we have even been observing a slight increase in the number of animals (Figure 1).

Among Polish native pigs the Pulawska breed is the oldest. Breeding activities started in 1926 for this breed. The original material comprised crossbreds of primitive prick-eared and long-eared pigs and populations called Nadwieprzańska and Poleska. In the course of breeding works to improve performance traits crossing was introduced, e.g. with the Large White and Berkshire breeds. The breed standard was

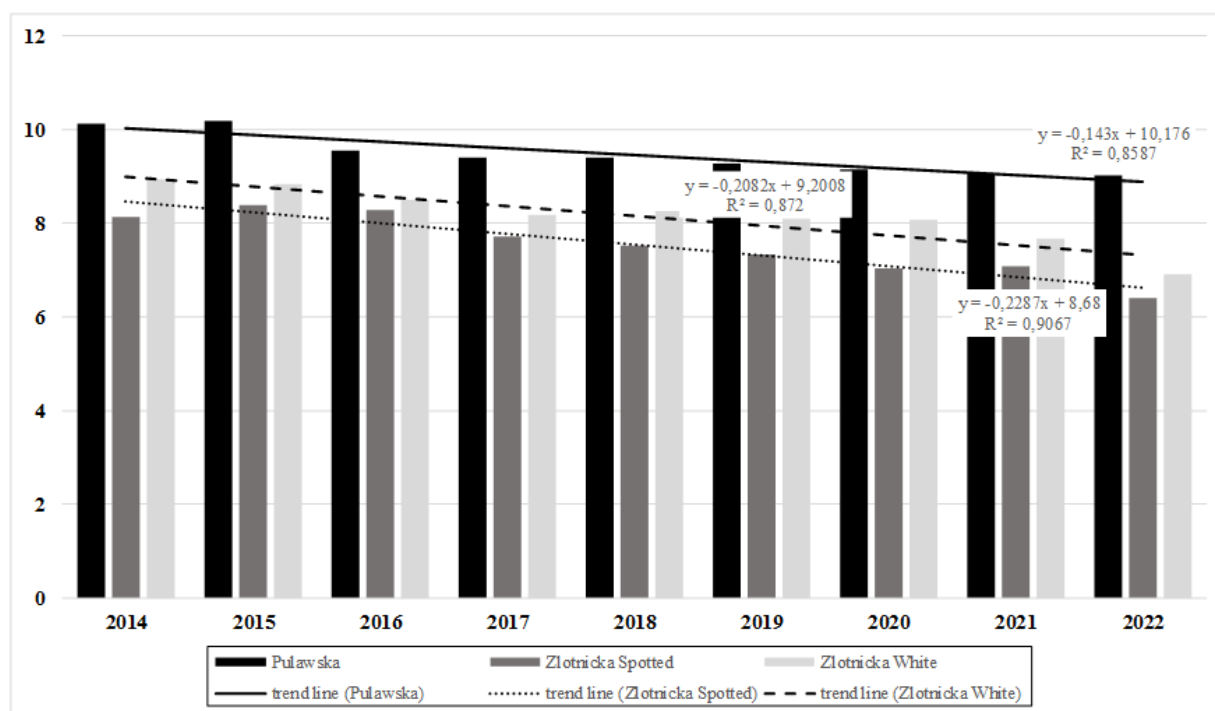
established in 1935. The breed is fat-meat type. It is characterized by high adaptability, good reproductive performance, longevity and a calm temperament. Meat and fat obtained from the Pulawska pigs show good technological and eating quality, for example: high intramuscular fat and protein contents, correct pH level and high water holding capacity and excellent sensory quality (Florowski et al., 2006 a, b; Kasprzyk et al., 2010; Babicz et al., 2013, 2016; Cebulska et al., 2018; Milczarek et al., 2019).

The Zlotnicka Spotted and Zlotnicka White breeds were generated after the Second World War at the Poznań University of Life Sciences based on primitive pigs originating from the area of Vilnius and Novogrudok (presently in Lithuania and Belarus, respectively). They were crosses of primitive Long-eared and Short-eared pigs with predominance of the former and possibly, a share of English Large White breed. In the successive years of breeding two color variants developed within the population: spotted and white. The former was improved only based on the evaluation, selection and pairing for mating. No crossing with other breeds was introduced to improve this breed. As a result the lard type Zlotnicka Spotted breed was generated, which until today has retained traits of its primitive ancestors.

The breed is characterized by high adaptability and longevity, it efficiently uses feeds of a high fiber content and it well tolerates harsh environmental conditions. Sows exhibit very good maternal instinct, while boars are characterized by high libido (Alexandrowicz et al., 1954; Domański and Buczyński, 1995).

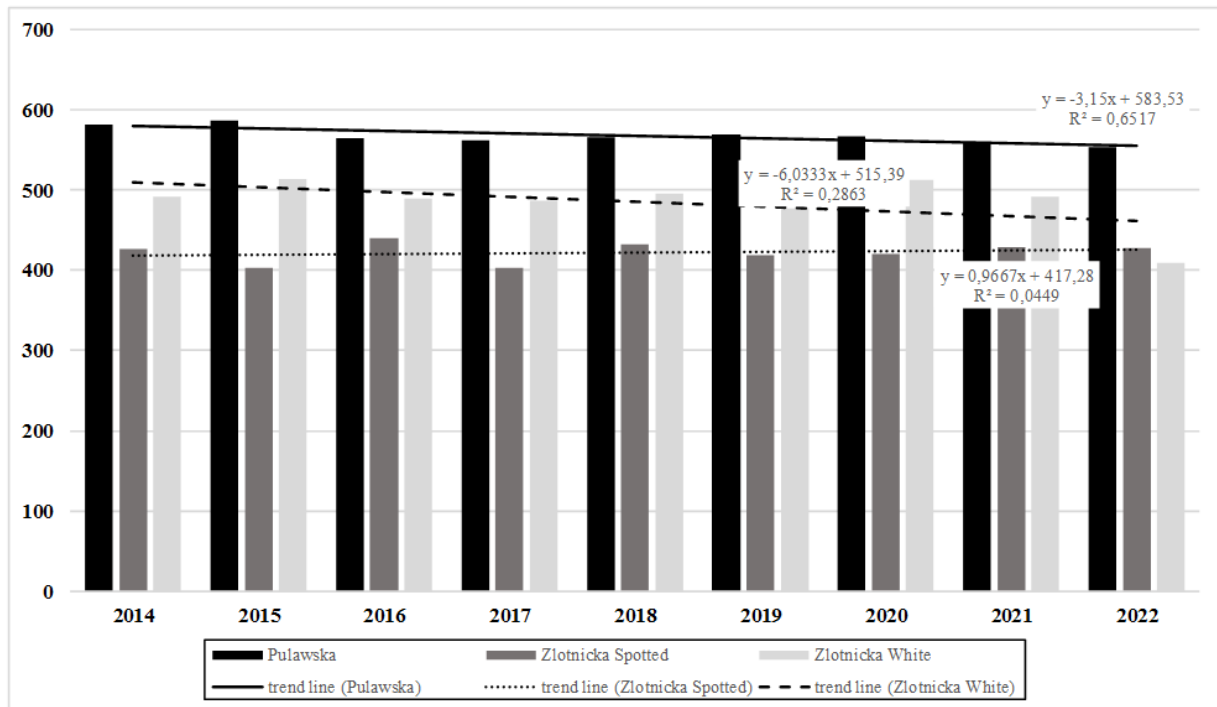
In turn, the white variant was improved using to a limited extent crossing with the Svensk Landrace (Sweden) and Polish Landrace (PL). By crossing, performance traits were improved with a simultaneous preservation of valuable traits of the original generation, such as resistance to environmental conditions, longevity and with modest demands for the pf-feed. Zlotnicka White sows show a low level of reproductive traits, like Zlotnicka Spotted and Pulawska (Figures 2 and 3). For all breeds, the coefficient of determination R^2 is very high (>0.85). This indicates a significantly decreasing time trend in the analyzed traits in the period under study (2014–2022).

They are caring mothers and good milk producers, with milk characterized by high nutrient contents (Skrzypczak et al., 2015). Both breeds, similarly as the Pulawska breed, exhibit good quality and processing aptitude of their meat (Grześkowiak et al., 2009; Migdał et al., 2017).



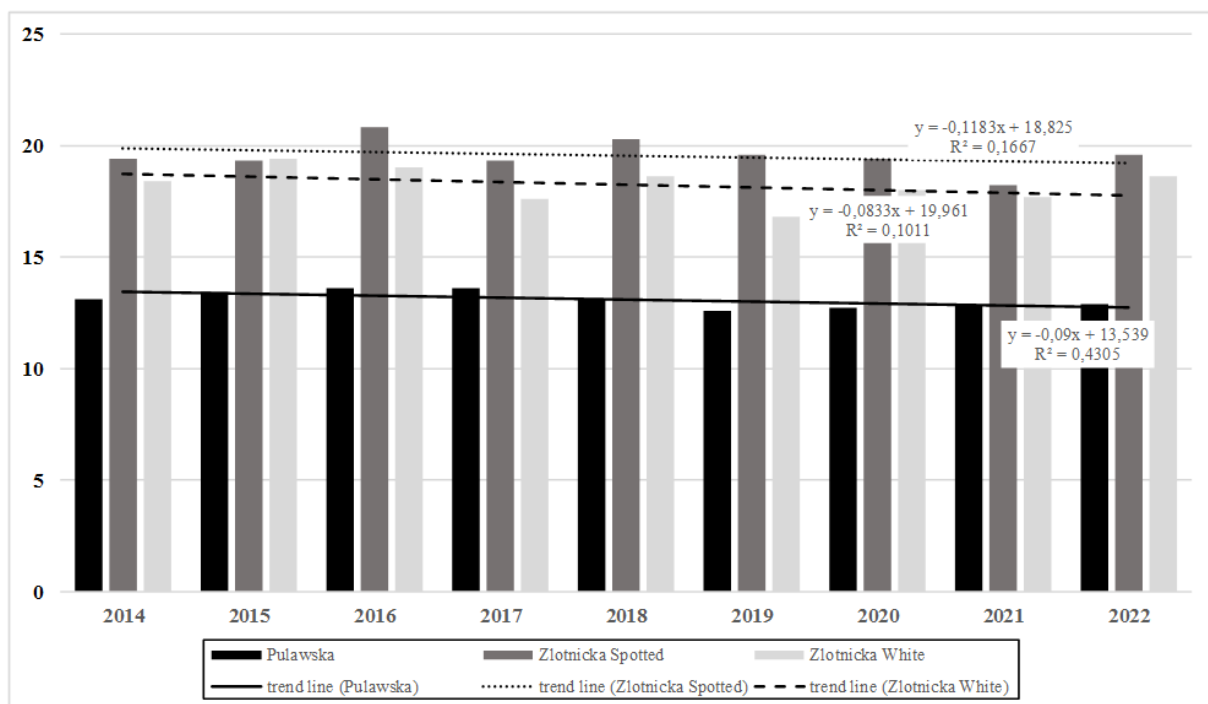
Source: <http://www.bioroznorodnosc.izoo.krakow.pl/bazy/stats/swinie>.

Figure 3. The mean number of piglets per litter on the 21st day of life in Polish native pig breeds in 2014–2022



Source: <http://www.bioroznorodnosc.izoo.krakow.pl/bazy/stats/swinie>.

Figure 4. The mean value of daily weight gain (g) in Polish native pig breeds in 2014–2022



Source: <http://www.bioroznorodnosc.izoo.krakow.pl/bazy/stats/swinie>.

Figure 5. The mean value of backfat thickness (mm) in Polish native pig breeds in 2014–2022

Slaughter and fattening traits of Polish native pigs

Figures 4, 5, and 6 present the results of the live measurements of gilts of Polish native pig breeds in

2014–2022 (<http://www.bioroznorodnosc.izoo.krakow.pl/bazy/stats/swinie>). These measurements are carried out in native breeds to monitor the level and variability

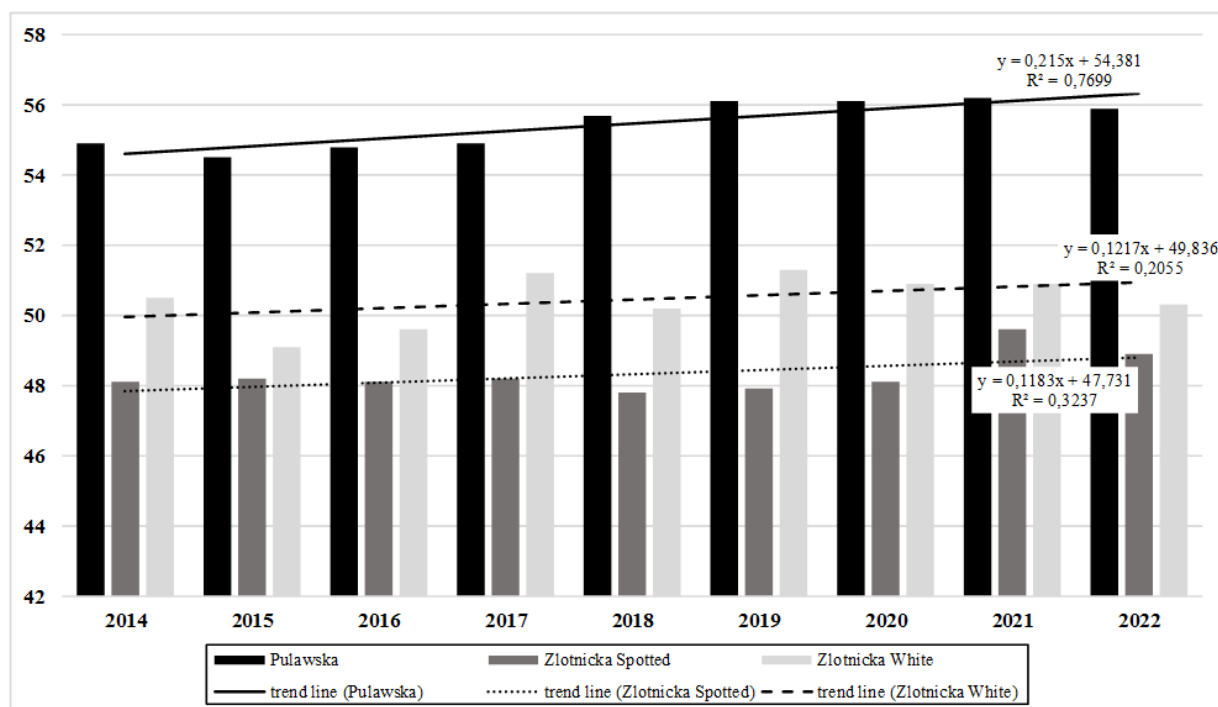
of performance characteristics. The daily weight gain, backfat thickness, and carcass leanness were considered. The highest level of traits was recorded for the Pulawska breed. The average daily gain in the analyzed period was 553–587 g, and the fat thickness ranged from 12.6 to 13.6 mm. However, the carcass leanness was approximately 55%. In turn, the lowest values of the examined traits were found for the Zlotnicka Spotted breed. Considering the coefficient of determination R^2 , in the case of Zlotnicka pigs, there are no significant changes in the value of traits over time. It was slightly different in the Pulawska breed, with a slight negative time trend for the analyzed trait (Figure 4). Analyzing the mean value of backfat thickness, no significant changes were observed over the years in the value of this trait ($R^2 = 0.1\text{--}0.4$; Figure 5). The most significant changes (positive time trend) in the mean value of carcass leanness (%) were observed only in Pulawska pigs, where the value of the coefficient of determination R^2 was above 0.7 (Figure 6).

Daily body weight gains range from 403 to 440 g. Similar results are also observed for Italian native breeds, Cinta Senese 436 g and Mora Romagnola 375 g (Franci and Pugliese, 2007). Zlotnicka Spotted gilts were characterized by low carcass leanness and considerable backfat thickness.

Daily weight gains

In Table 2, slaughter and fattening traits in fatteners of Polish native pig breeds were shown. Among Polish local breeds Pulawska fatteners exhibit the highest daily body weight gains ranging from 780 to 692 g (Tyra and Żak, 2010; Milczarek, 2021). Nevertheless, they are lower than those recorded for the Polish Large White and Polish Landrace pigs – the two most popular meat breeds kept in Poland (POLSUS, 2011, 2023).

In turn, a slower rate of body weight gains was reported by researchers for the Zlotnicka White and Zlotnicka Spotted breeds. Many authors recorded daily body weight gains below 500 g in Zlotnicka White fatteners (Domański, 1981; Domański and Maruniewicz, 1981; Tratwal and Domański, 1986; Buczyński et al., 2005). The markedly lower growth rate below 300 g a day for this breed was found by Domański et al. (1999). Study of Szyndler-Nęcza et al. (2021) showed that, depending on the feeding system (extensive and intensive), the Zlotnicka Spotted breed has an average daily gain of 340 to 580 g/day, respectively. Similar results, 300–307 g/day, were reported Cosentino et al. (2003) for Italian native breed Calabrese and Václavková et al. (2018) for the Prestice Black-Pied breed (555–576 g/day). Such low body weight gains were also given by Pugliese et al. (2003) and Radović et al. (2017) for the Mangalitsa and Nero Siciliano breed, in which they were even below 300 g.



Source: <http://www.bioroznorodnosc.izoo.krakow.pl/bazy/stats/swinie>.

Figure 6. The mean value of carcass leanness (%) in Polish native pig breeds in 2014–2022

Table 2. Slaughter and fattening traits in fatteners of Polish native pig breeds

Breed	Author	<i>n</i>	Body weight (kg)	Daily weight gain (g)	Carcass leanness (%)	Backfat thickness (mm)
Pulawska	Babicz et al. (2009)	30	130	–	–	40.8–40.9
	Tyra and Żak (2010)	104	100	780	55.1	19.2
	Wojtysiak and Połtowicz (2014)	28	100	–	45.30	23.64
	Milczarek and Osek (2016)	48	117	749–768	52.08–52.50	31.05–34.65
	Bogucka and Kapelański (2016)	10	–	–	–	31.24
	Piórkowska et al. (2018)	8	100	763	59.5	16.4
	Babicz et al. (2020)	50	112	810	56.26	12.73
	Milczarek (2021)	20	102	692	50.6	28.68
Zlotnicka Spotted	Grześkowiak et al. (2009)	30	105	–	46.28	32.11
	Bocian et al. (2012)	61	102	–	–	29.49
	Szulc et al. (2012 a)	20	116	590	41.83	34.96
	Bogucka and Kapelański (2016)	24	102	–	–	23.72
	Szyndler-Nędza et al. (2021)	7	100	340–580	–	–
Zlotnicka White	Domański (1981)	942	–	443	–	26.2
	Domański and Maruniewicz (1981)	504	120	451.3	–	25.1
	Tratwal and Domański (1986)	907	120	447.3	–	28.73
	Domański and Buczyński (1995)	2362	–	–	–	28.31
	Domański et al. (1998)	2060	120	–	–	27.70
	Domański et al. (1999)	729	110–120	266.1	–	25.41
	Buczyński et al. (2005)	19	110	484	46.73	21.26–21.94
	Grześkowiak et al. (2009)	30	105	–	46.33	34.73

Carcass leanness

As it can be observed from Table 2, Pulawska and Zlotnicka White pigs are characterized by medium carcass leanness amounting to 50–55% in breeding animals. Similar levels of carcass leanness were also observed in the Prestice Black-Pied breed – 52.70% (Dostálová et al., 2012). In fatteners of this breed the greatest carcass leanness was reported by Piórkowska et al. (2018) also for the Pulawska breed, in which it was 59.5%. Carcass leanness was comparable to the values for the Polish Large White, Polish Landrace, Hampshire, Duroc and Pietrain breeds as well as hybrid line 990. This line was bred in the National Research Institute of Animal Production, Poland (Tyra and Żak, 2010; Bocian et al., 2012). In turn, Wojtysiak and Połtowicz (2014) for Pulawska pigs observed a very low carcass leanness, amounting to as little as 45.30%. This result was comparable to those reported for the Zlotnicka Spotted breed, for which the value of this trait ranged from 41.83 to 46.28% (Grześkowiak et al., 2009; Szulc et al., 2012 a). Similar results were obtained by Đikić et al. (2010) for the Turpolje breed at 45.3% as well as Čandek-Potokar et al. (2003) for the Krškopolje breed at 46.2%. However, Turopolje and Krškopolje can be defined as a late maturing and fatty type of pig as Zlotnicka Spotted. In turn, Matoušek et al. (2016) for Prestice Black-Pied pigs reported carcass leanness of 48.76–48.94%. Václavková et al. (2018) for Prestice Black-Pied pigs found a greater carcass leanness (61.3–61.8% depending on the sex). In another study, Brandt et al. (2010), among European native breeds, reported for the Angler Sattelschwein and Schwäbisch-Hällisches breeds and the trait value was 49.0 and 51.7%, respectively. The carcass leanness in the case of Angler Sattelschwein was greater in the conventional housing system than in the organic system. The authors observed

the opposite situation in the Schwäbisch-Hällisches breed case.

Backfat thickness

In the case of backfat all fatteners of Polish native pig breeds exhibit its considerable thickness (16.4–40.9 mm – Table 2). Only in two studies for Pulawska pigs backfat thickness below 20.0 mm was recorded. In a study by Tyra and Żak (2010) the mean backfat thickness was 19.2 mm, while in a study of Piórkowska et al. (2018) backfat thickness of 16.4 mm was observed. At the same time, the greatest subcutaneous fat thickness was observed in this breed (Babicz et al., 2009). Čandek-Potokar et al. (2019) reported considerable variability between European native breeds for similar traits, such as fat layer thickness. The thinnest fat layer was found in the Bísara breed (30.0 mm), while the thickest was observed in the Iberian (51.0 mm), Mangalitsa (54.0 mm), Majorcan Black (58.0 mm) and Moravka (59.0 mm).

The variability in fattening performance traits observed in Polish native pig breeds in relation to slaughter performance traits is the result of different performance types. In herds keeping pigs of native breeds various housing systems are used, both indoor and outdoor. In these breeds also the conservation character of the breeding system (lack of any selection work towards improvement of traits) leads to a situation when animals representing one breed may differ considerably in the levels of analyzed traits (showing high variability). Similar observations were reported by Franco et al. (2016) for the Celta breed, in which backfat thickness ranged from 48 to 57 mm. In turn, Pugliese et al. (2004) for the Italian pig breed Nero Siciliano showed a significant effect of the adopted housing system on the height at the withers, shoulder width, body length and carcass length as well

as total backfat thickness. Also Dostálová et al. (2012) found significant differences in values of fattening and slaughter traits for the Prestice Black-Pied breed depending on the housing system, i.e. organic free-range vs. conventional. In turn, Petrović et al. (2012) recorded the effect of the management system only in the case of backfat thickness.

Muscle composition

Water content

Table 3 presents results on the chemical composition of the *thoracis et lumborum* muscle in Polish native pig breeds. Results obtained by most researchers indicate that the mean water content in the Pulawska breed is around 72–73% (Florowski et al., 2006 a, 2007; Babicz et al., 2009; Milczarek and Osek, 2016; Milczarek et al., 2019). A slightly higher value (74.24%) was reported by Milczarek (2021). In turn, investigations by Debrecéni et al. (2018) showed a slightly lower water content (69.8%) in meat from pigs of that breed. For the Zlotnicka Spotted breed water content ranged from 70.5% (Debrecéni et al., 2018) to 73.64% (Jankowiak et al., 2010). In the Zlotnicka White breed the results given by all those authors were similar. The lowest water content of muscles (72.40%) was recorded in a study by Grześkowiak et al. (2009), while the highest (74.84%) was in pigs from a study by Domański and Ratajszczak (1994). It needs to be

emphasized here that the muscles of Polish native pig breeds are characterized by a lower water content compared to highly productive breeds, such as the Polish Landrace (Florowski et al., 2006 b; Babicz et al., 2013; Kasprzyk, 2015) and Polish Large White breeds (Stasiak and Kamyk, 2001), or PL × PLW crosses (Milczarek et al., 2012).

Intramuscular fat content (IMF)

Intramuscular fat content (IMF) presents a significant meat quality trait, especially from nutritional quality aspect (Blicharski et al., 2013). Due to the acute selection of pigs to improve fattening and slaughter traits, both backfat thickness and the amount of intramuscular fat have decreased with the increase in carcass leanness. (Schwab et al., 2007; Borzuta and Lisiak, 2016; Sieczkowska et al., 2017). The mean intramuscular fat content in the Landrace and Large White breeds does not exceed 2% (Stasiak and Kamyk, 2001; Florowski et al., 2006 b; Guo et al., 2011; Tyra and Žak, 2010; Babicz et al., 2013; Bereta et al., 2014; Kasprzyk, 2015; Yao et al., 2021). In contrast, according to many authors to ensure optimal sensory quality IMF needs to be 2–3.5% (Affentranger et al., 1996; Wood et al., 1999; Olkiewicz et al., 2006; Tyra, 2013). Such level is observed in many native European pig breeds. Labroue et al. (2000) recorded IMF at 2.9–3.9% for Basque, Gascon, Limousine and Blanc de l'Ouest pig breeds.

Table 3. The composition of the *musculus longissimus thoracis et lumborum* of Polish native pigs

Breed	Author	n	Water content (%)	IMF (%)	Protein content (%)
Pulawska	Florowski et al. (2006 a)	17	73.7	2.5	22.4
	Florowski et al. (2007)	10	71.60	3.7	22.00
	Babicz et al. (2009)	30	73.05–73.09	2.51–2.53	23.10–23.12
	Kasprzyk et al. (2013)	30	73.99	2.20	22.40
	Babicz et al. (2013)	20	–	2.41	23.27
	Kasprzyk et al. (2015)	20	–	2.58	22.54
	Milczarek and Osek (2016)	48	72.70–72.75	3.00–3.05	23.02–23.12
	Wojtysiak and Połtowicz (2014)	28	–	3.33	–
	Debrecéni et al. (2018)	10	69.8	5.5	23.3
	Cebulska et al. (2018)	15	70.76	4.07	23.67
	Piórkowska et al. (2018)	8	–	1.19	–
	Milczarek et al. (2019)	30	72.70–73.06	2.94–3.08	22.90–23.12
	Kasprzyk and Bogucka (2020)	30	73.15	2.73	22.90
	Milczarek (2021)	20	74.24	1.91	22.72
Zlotnicka Spotted	Florowski et al. (2006)	17	73.3	3.1	22.3
	Grześkowiak et al. (2009)	30	73.53	2.04	23.27
	Jankowiak et al. (2010)	30	73.64	2.17	22.79
	Szulc et al. (2012 b)	20	71.74	3.44	24.54
	Bocian et al. (2012)	61	–	1.87	–
	Debrecéni et al. (2018)	10	70.5	2.6	25.2
	Cebulska et al. (2018)	15	70.89	2.25	25.23
	Szyndler-Nędzka et al. (2021)	7	71.69–72.95	2.17–3.60	23.22–23.43
Zlotnicka White	Domański and Maruniewicz (1981)	504	73.05	–	–
	Tratwal and Domański (1986)	907	74.53	–	–
	Domański et al. (1996)	876	74.84	1.77	–
	Grześkowiak et al. (2009)	30	72.40	1.87	24.50
	Migdał et al. (2017)	6	73.7	3.0	21.7

Table 4. Physical properties of the *longissimus thoracis et lumborum* originating from Polish native pigs

Breed	Author	Traits								
		n	pH ₄₅	pH ₂₄	Color			Drip loss (%)	Cooking loss (%)	WHC (%)
					L*	a	b			
Pulawska	Kasprzyk et al. (2013)	30	6.38	5.67	48.75	16.99	5.04	4.20	27.46	20.03
	Kasprzyk et al. (2015)	20	6.15	5.59	52.45	3.19	9.65	3.71	—	—
	Wojtyśiak and Poltowicz (2014)	28	6.71	5.64	47.16	14.36	3.39	1.75	35.92	18.31
	Mileczarek and Osek (2016)	48	6.14–6.15	5.53–5.61	51.43–53.48	16.08–16.78	1.75–1.94	1.64–2.22	—	19.85–20.75
	Mileczarek et al. (2019)	30	6.10–6.11	5.61–5.58	52.60–53.17	13.29–14.97	2.02–2.36	1.68–2.18	—	20.41–21.03
	Cebulska et al. (2018)	25	6.55	5.71	52.86	15.97	3.53	2.26	24.89	18.07
	Piórkowska et al. (2018)	8	6.32	5.60	53.72	16.16	2.25	—	—	—
	Kasprzyk and Bogucka (2020)	30	6.19	5.61	54.94	—	9.84	2.73	26.27	—
	Mileczarek (2021)	20	6.30	5.60	51.2	8.67	0.76	—	—	20.4
	Szulc et al. (2012 b)	20	6.39	5.50	46.43	8.17	2.89	2.36	27.91	32.66
Złotnicka Spotted	Szulc et al. (2012 a)	20	6.15	5.42	50.46	4.06	7.89	—	—	—
	Bogucka and Kapelański (2016)	24	6.57	5.69	49.30	17.22	2.53	—	—	18.56
	Cebulska et al. (2018)	25	6.25	5.61	49.19	17.45	2.66	2.95	21.80	18.59
	Debrecéni et al. (2018)	10	6.4	5.6	49.2	2.7	17.8	—	—	—
	Domański and Maruniewicz (1981)	504	6.34	5.70	—	—	—	—	29.64	—
Złotnicka White	Domański and Ratajszczak (1994)	876	6.08	5.52	—	—	—	—	29.19	—
	Domański and Buczyński (1995)	236	6.22	5.66	—	—	—	—	—	—
	Ratajszczak and Buczyński (1997)	869	6.40–6.60	—	—	—	—	—	—	—
	Grześkowiak et al. (2009)	30	6.38	5.53	43.88	6.27	4.95	3.36	27.62	29.88
	Migdał et al. (2017)	6	—	5.72	49.54	14.23	3.34	—	22.76	—

In turn, Nevrkla et al. (2021) noted for Prestice Black-Pied IMF at 2.38%. A high intramuscular fat content was also reported for Italian native pig breeds by Pugliese et al. (2004) for Nero Siciliano (3.3–4.3%), by Fortina et al. (2005) for Casertana (4.7%) and Mora Romagnola (6.1%). Franco et al. (2014) specified IMF for the Celta breed at 5.22%. For the Black Slavonian, Moravka and Mangalitsa breeds studies conducted to date showed a high intramuscular fat content (Senečič et al., 2005; Karolyi et al., 2007; Petrović et al., 2012).

In relation to the results given above concerning Polish native pig breeds the highest IMF, amounting to 5.5%, was recorded for the Pulawska breed (Debrecéni et al., 2018). In five studies the intramuscular fat content did not reach 2%, for Pulawska (Piórkowska et al., 2018; Milczarek, 2021), for Zlotnicka Spotted (Bocian et al., 2012) and for Zlotnicka White (Domański et al., 1996; Grześkowiak et al., 2009). In Table 3 a variation in the results within individual breeds can be observed. This is most markedly evident in the Pulawska breed, in which Debrecéni et al. (2018) found IMF of 5.5%, while in a study by Piórkowska et al. (2018) it was as little as 1.19%. However, in the case of local pig breeds, in which the aim of breeding is to preserve biodiversity within the population, the variability of values for specific traits is not only typical, but also advantageous. An example outside Poland may be Iberico with the intramuscular fat content ranging from 3.27 to 29.21%, average 9.9% (Fernández et al., 2007).

Protein content

Results presented in Table 3 indicate that protein content in the case of fatteners of local genotypes pig breeds ranges from 21.7% for the Zlotnicka White (Migdał et al., 2017) to 25.23% for the Zlotnicka Spotted breed (Cebulska et al., 2018). Similar results were obtained by Stasiak and Kamyk (2001), Florowski et al. (2006 b), Babicz et al. (2013), Kasprzyk et al. (2015), and Migdał et al. (2017) for the Polish Landrace and Polish Large White breeds, Petrović et al. (2010) for the Moravka and Mangalitsa breeds, as well as Auqui et al. (2019) for the Chato Murciano breed. In turn, a slightly lower protein content was recorded by Migdał et al. (2017) for Mangalitsa (20.07%) and Moravka (20.2%).

Physical properties of *longissimus thoracis et lumborum*

The physical properties of meat, which are determinants of its quality, are influenced by several environmental factors apart from the genotype. The most important include nutrition, housing conditions, season, and pre-slaughter handling (Vermeulen et al., 2015; Składanowska-Baryza and Stanisław, 2019; Sardi et al., 2020). However, currently, the regulations on the keeping, transport, and slaughter of pigs ensure the minimization of the negative impact of the above factors on the quality of pork (Act, 1997; Council Regulation (EC), 2004; Official Journal of the European Union, 2009).

pH level

Initial pH values given in Table 4 for all the investigated breeds were according to the criteria for normal meat (≥ 6.0). Koćwin-Podsiadło et al. (2006), Strzelecki et al. (2007), and Sieczkowska et al. (2019) indicate that a pH_{45} level below 6.0 can often be related to PSE meat defect. None of the cited authors found a high acidification level ($\text{pH}_{24} \geq 6.0$ – 6.2) characterizing DFD meat. Analogous results were obtained for native pig breeds such as Mangalitsa and Moravka, crosses of Mangalitsa and Iberico (Straadt et al., 2013; Radović et al., 2017; Migdał et al., 2017), Calabrese (Cosentino et al., 2003), Cinta Senese, Mora Romagnola and Nero Siciliano (Franci and Pugliese, 2007), Chato Murciano and Celta (Franco et al., 2014) and Prestice Black-Pied (Matoušek et al., 2016).

Color

Warriss and Brown (1995) showed that the value of L^* within the range of 49–60 for the *longissimus dorsi* muscle is perceived as desirable by consumers. An excessively pale meat color is undesirable to consumers and also indicates the PSE meat defect (Warriss and Brown, 1995; Joo et al., 1999; Gajewczyk et al., 2014). Polish native breeds color is darker – from 43.88 to 54.94 (Table 4), than that observed in Polish Landrace – 56.52 by Kasprzyk et al. (2015), and 53.07–54.26 by Wojtysiak and Kaczor (2011). The darkest meat color – 43.88 was recorded for the Zlotnicka White breed (Grześkowiak et al., 2009), with L^* being similar to that recorded by Marsico et al. (2007) for wild boars – 43.63. The result was also similar to those observed for Chato Murciano by Auqui et al. (2019) for Mora Romagnola, Casertana, and Nero Siciliano (Cosentino et al., 2003; Fortina et al., 2005). The meat of Zlotnicka Spotted pigs was also characterized by a dark color (L^* 46.43–50.46), similarly as it was the case for Nero Siciliano – 46.7 (Pugliese et al., 2004), and Cinta Senese – 49.7 (Franci et al., 2005). In turn, results recorded for the Pulawska breed were consistent with those recorded for Prestice Black Pied pigs (Migdał et al., 2017).

Drip loss and cooking loss

Drip loss for native pig breeds in most cases was low (Table 4). Generally, the values for this trait were 2–3% for meat from different breeds. Similar results were reported for the Black Slavonian pig (Kuśec et al., 2022) and Celta pig – varieties Carbalina and Santiaguesa slaughtered at 12 months of life (Franco et al., 2014). In the studies presented in Table 4 the highest drip loss was recorded by Kasprzyk et al. (2013) for Pulawska pigs. In the same breed the lowest drip loss (up to 1.75%) was observed (Wojtysiak and Połtowicz, 2014). Water losses during cooking were similar in all Polish native breeds. The highest values were reported by Wojtysiak and Połtowicz (2014) for Pulawska pigs (35.92). The authors emphasize that the result was significantly lower than that recorded in the same research

for the Polish Large White breed, where the cooking loss was 38.09. They indicate possible negative correlations between pH_{24} and drip loss and cooking loss. The lower cooking loss found by Wojtysiak and Połtowicz (2014) at a higher pH_{24} (5.63) in the Pulawska breed compared to the PLW ($pH_{24} = 5.48$) indicates good water binding in the muscle and better suitability of the meat for processing. The lowest levels were recorded by Cebulska et al. (2018) in the Zlotnicka Spotted breed at 21.80%. Similar results were obtained by Franco et al. (2016) for Celta Carbalina pigs. In turn, Migdał et al. (2017) found a greater cooking loss for the Mangalitsa (25.76%) and Moravka breeds (24.7%).

Water holding capacity (WHC)

One popular free water determination method is the Grau-Hamm method (Grau and Hamm, 1952; Pohja and Niinivaara, 1957). The water-holding capacity of meat is described as the ability of the post-mortem muscle to retain water even though external pressures are applied to it. This method is easy and fast, does not need special equipment, and is an essential indicator of meat processability (Volpato et al., 2008). This trait has a considerable effect on meat juiciness and tenderness as well as changes in meat water content during meat handling and thermal processing (Modzelewska-Kapituła and Cierach, 2012). For Polish native breeds WHC ranged from 29.88% for the Zlotnicka White (Grześkowiak et al., 2009) to 18.31% for the Pulawska breed (Wojtysiak and Połtowicz, 2014).

Fatty acids profile

The profile of fatty acids in meats originating from Polish native breeds is shown in Table 5. The acid profile influences the dietary value and determines the health-promoting properties of the meat. The level of PUFA from the n-3 and n-6 groups is fundamental because the human body does not synthesize the acids and must be supplied with the diet. These fats determine the proper functioning of cell tissues, the central nervous system, and the retina (Achremowicz and Szary-Sworst, 2005). Studies have also shown that n-3 PUFAs reduce the risk of coronary artery disease and cancer (Bucher et al., 2002; Bee et al., 2004).

In studies presented in Table 5, the highest share of saturated fatty acids (SFA) was recorded by Jankowiak et al. (2010) and Szyndler-Nędza et al. (2021) for the Zlotnicka Spotted breed. The lowest SFA content was found for the Pulawska breed; it was 35.84% (Milczarek et al., 2019). Similar results were obtained by Zhao et al. (2009), and Parunović et al. (2013) for the White Mangalitsa and Swallow Bellied Mangalitsa. Also, Razmaite et al. (2021) reported similar results for the Lithuanian Indigenous Wattle breed, with the share of SFA being 36.28%. While, Nevrla et al. (2023) found a higher SFA content 39.87–54.31% for Prestice Black-Pied pig. As for the level of monounsaturated fatty acids (MUFA), the highest values were observed in pigs of

the Pulawska breed. They ranged from 51.45% (Kasprzyk et al., 2015) to 61.68% (Milczarek and Osek, 2016). Similar results were obtained by Furman et al. (2010) for Krškopolje pig (45.28–63.70%) and by Parunović et al. (2013), who observed a MUFA of 58.00% for the White Mangalitsa breed. Lower values were found for the Zlotnicka Spotted and Zlotnicka White breeds. In turn, in relation to polyunsaturated fatty acids (PUFA), the Zlotnicka Spotted and Zlotnicka White breeds were characterized by a higher content than Pulawska pigs. In the meat of Zlotnicka Spotted pigs, the level of PUFA ranged from 4.25% (Szyndler-Nędza et al., 2021) to 15.19% (Cebulska et al., 2018). On the other hand, research on the fatty acid profile of Zlotnicka White has so far been conducted to a minimal extent (Grześkowiak et al., 2009). The SFA level recorded for this breed was 39.41%, for MUFA – 47.36%, and PUFA – 12.94%.

An important indicator determining the nutritional value of fat is the ratio of n-6 PUFA to n-3 PUFA. As indicated by Grześkowiak et al. (2010), the correct ratio of polyunsaturated fatty acids from the n-6 to n-3 family in the daily food ration should be in the range of 6:1 to 4:1. In the studies on Polish native breeds this ratio varied from 8.79 for Pulawska (Cebulska et al., 2018) to 13.82 for Zlotnicka Spotted (Migdał et al., 2017). Aipătioaie et al. (2022) determined lower values n-6/n-3 ratio for native breeds Bazna (1.72) and Red Mangalitsa (1.84). Grześkowiak et al. (2010) and Furman et al. (2010) obtained a much higher indicator for Polish Landrace × Polish Large White – 14.90, Polish Landrace × (Duroc × Pietrain) – 15.01 and Krškopolje pig – 14.33. A higher proportion was shown by Kasprzyk et al. (2015) in the meat of Polish Landrace pigs, where it was 15.61. In turn, Nevrla et al. (2023) recorded the ratio from 6.60 to 6.73 for Prestice Black-Pied pig.

Sensory traits

High-quality meat should have features consumers desire because sensory evaluation is often the basis for purchasing decisions. The data presented in Table 6 indicate that meat obtained from Polish native breeds is of excellent sensory quality. All features: tenderness, juiciness, palatability, flavor, and tastiness (desirability, intensity) were rated above 4 on a 5-point scale. Study of Florowski et al. (2005) showed that Zlotnicka Spotted meat scored higher than Pietrain and wild boar meat in the tenderness assessment. However, in terms of juiciness, it was close to wild boar.

Conclusions

The broadly understood quality of pork is affected by a variety of factors, with breed being one of the most important ones. The results presented in this manuscript show that Polish native pig breeds have an excellent meat quality. Compared to other breeds used in breeding herds in Poland their meat exhibits high intramuscular fat and protein content.

Table 5. Fatty acid profile (% of the total fatty acids) and fatty acid ratios in intramuscular fat of the *longissimus thoracis et lumborum* originating from Polish native pigs

	Author	n	SFA	MUFA	PUFA	PUFA n-3	PUFA n-6	n-6/n-3
Pulawska	Kasprzyk et al. (2015)	20	37.79	51.45	10.77	—	9.45	12.68
	Milczarek and Osek (2016)	48	41.25–41.90	55.09–55.98	2.39–2.95	—	—	—
	Migdał et al. (2017)	6	—	—	—	0.75	9.58	12.77
	Cebulska et al. (2018)	15	37.79	52.72	9.32	0.97	8.36	8.79
	Debreceńi et al. (2018)	10	38.16	52.45	9.23	0.94	8.29	8.89
	Milczarek et al. (2019)	30	35.84–37.84	60.19–61.68	1.9–2.78	—	—	—
Złotnicka Spotted	Grześkowiak et al. (2009)	30	38.18	49.41	11.08	0.94	10.14	10.78
	Jankowiak et al. (2010)	60	43.84	46.58	—	—	—	—
	Migdał et al. (2017)	6	—	—	—	0.79	10.92	13.82
	Cebulska et al. (2018)	15	37.20	47.37	15.19	1.06	14.13	13.39
	Debreceńi et al. (2018)	10	36.95	47.70	15.09	1.08	14.01	12.94
	Szyndler-Nędza et al. (2021)	7	41.72–43.50	51.10–53.98	4.25–5.32	0.30–0.47	3.95–4.85	10.32–13.17
Złotnicka White	Grześkowiak et al. (2009)	30	39.41	47.36	12.94	1.10	11.84	10.73
	Migdał et al. (2017)	6	—	—	—	0.27	3.47	12.77

SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, PUFA n-3 – sum of all n-3 polyunsaturated fatty acids identified, PUFA n-6 – sum of all n-6 polyunsaturated fatty acids identified, n-6/n-3 – ratio Σ n-6 PUFA to Σ n-3 PUFA.

Table 6. Results of sensory evaluation of the *longissimus thoracis et lumborum* originating from Polish native pigs (points)*

	Author	n	Tenderness	Juiciness	Palatability		Flavor		Tastiness	
					desirability	intensity	desirability	intensity	desirability	intensity
Pulawska	Kasprzyk et al. (2010)	8	4.60	4.70	—	—	4.60	4.70	4.60	4.60
	Kasprzyk et al. (2013)	30	4.50	4.40	—	4.6	—	4.70	—	—
	Milczarek and Osek (2016)	48	4.25–4.87	4.37–4.87	4.77–4.87	4.00–4.75	4.75	4.62	—	—
	Babiez et al. (2013)	20	4.83	4.87	—	—	—	—	4.93	4.67
Złotnicka Spotted	Szulc et al. (2012 b)	20	4.16	4.12	—	4.30	—	4.37	—	—

*Sensory traits were evaluated according to a 5-point scale: from 1 (minimum) to 5 (maximum).

Acidification after slaughter is typical for normal meat. This meat is characterized by a darker color, high water holding capacity and excellent sensory quality. In Poland efforts are being made to increase the use of meat from the Puławska, Złotnicka Spotted and Złotnicka White breeds. Currently this meat is gaining in popularity, particularly among consumers searching for products of superior quality.

Author contributions

All the authors have contributed equally to this work. All the authors have read and agreed to the published version of the manuscript.

Conflicts of interest

The authors declare no conflict of interest

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