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Original scientific paper

Effect of rearing system on carcass properties, chemical content and fatty acid composition of backfat from Mangalitsa pigs

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A b s t r a c t: This research examined the effects of two rearing systems (conventional versus free-range) on carcass characteristics, and cholesterol content, chemical and fatty acid properties of the backfat from Mangalitsa pigs. Depending on the rearing system utilized and live weight observed, we found important differences in the heaviness of the cold and warm Mangalitsa carcasses. The maximum total cholesterol in the backfat of pigs reared outdoors was 46.96 mg kg^{-1}, while the maximum total cholesterol in backfat of conventionally-raised Mangalitsa pigs was 55.80 mg kg^{-1}. The backfat from free-ranging Mangalitsa pigs contained lower levels of PUFA n-6 and greater amounts of PUFA n-3. The ratio of PUFA/SFA was remarkably different in pigs raised in the two systems, whereas the ratio of MUFA/SFA was lower in the pigs reared outdoors. Based on these results, the selection of rearing system could affect the chemical properties and carcass characteristics of Mangalitsa backfat.

Keywords: *rearing system; indigenous breed; carcass traits; backfat; cholesterol; fatty acids.*

Introduction

The Mangalitsa, a fatty type of pig, is an autochthonous swine breed in Serbia, where it has been present for more than 100 years. Today, breeding Mangalitsa pigs are commercialized by processing the high quality meat into products to attract growing interest in the food production and consumer markets. The Mangalitsa pig's future is heavily dependent on whether products derived from it can be used effectively, and whether long-term markets can be secured. Today, consumers not only select meat products according to perceived eating quality and accessible pricing, but they also consider the nutritional value and the ethical meat quality, as well as animal welfare issues and the level of impact on the environment caused by the production system. Another reason for choosing ecologically, non-intensively produced meat is the opinion that the flavour and nutritive value of this type of meat are superior as compared to meat grown in the conventional way (*Mapiye et al*., 2011, *Parunovic et al*., 2012a). The aim of this study was to explore differences between carcass properties, chemical and fatty acid composition and the cholesterol content in backfat of free-range and conventionally reared Mangalitsa pigs.

Materials and methods

Twenty-four castrated male Mangalitsa pigs were selected from a herd in a breeding programme. Twelve of the Mangalitsa pigs were raised conventionally — six pigs per pen, allowing 6 m^2 living space for each animal. These uniform pens were part of a group inside a pig farmer's shed, which was enclosed by walls and covered with a roof. The airflow was controlled manually by opening or closing the windows. The floor of the pens was concrete, and one third had concrete slats above a faeces and urine drainage channel. The other 12 Mangalitsa pigs were allowed to range freely over an area of 8 000 m^2, and so had regular access to fresh grass pasture and fallen acorns.

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After reaching a live weight of 60 kg, both groups of pigs were fed a conventional slaughter-pig feeding mixture that was distributed *ad libitum*. The composition of this compound feed is given in Table 1.

Table 1. Feed ingredient composition and estimated analyses of the diet

Ingredients [a]	**(% as-fed)**
Maize	70.0
Meal [b]	14.0
Soybean meal [c]	9.0
Sunflower meal	4.0
Chalk	1.0
Dicalcium phosphate	1.0
Sodium chloride	0.5
Lysine	0.15
Methionine and Threonine supplement	0.15
Total	100.00
Estimated nutrient content [d] *(%)*	
Crude protein (N × 6.25)	13.00
Crude fat	3.62
Crude dietary fibre	3.87
Crude ash	4.88
ME content, MJ kg^{-1}	13.05

Legend: [a] Ingredient composition (% as-fed); [b] (wheat feed flour, barley, wheat, oats, dehydrated lucerne flour); [c] (soya press cake, soya protein concentrate with fish oil) [d] Estimated analyses (%)

At the end of the trial, at live weights of between 80 kg and 120 kg, the Mangalitsa pigs were transported in the morning to the nearby commercial abattoir in Jagodina (approximately 8 km) in groups of a maximum of 6 animals. Pig groups were not mixed during transport. The animals were slaughtered at similar live weights (100 kg), but not similar ages, because this enabled slaughter and transport procedures to be standardized; differences in carcass weights among animals of similar ages would have overruled other effects on carcass conformation or meat quality.

The body weight of the trial pigs was measured prior to and shortly after slaughter. Carcasses contained heads, trotters and kidney fat. Each carcass was weighed warm and then chilled (4°C for 24 h). After 24 h of cooling at 4°C, backfat measurements were taken with a ruler above the *m. gluteus medius* at the carcass split-line, at these positions: at the beginning (P1); at the highest spot of the *m. gluteus medius* (P2), and; at the end of the muscle (P3). Carcass length was measured from the cranial edge of the *symphisis pubis* to the anterior edge of the atlas vertebrae. During routine carcass splitting and cutting, samples of the backfat were taken between the 13^{th} and 15^{th} thoracic vertebrae. Prior to laboratory analysis, all the samples were vacuum packed and kept frozen at approximately −20°C.

Chemical composition was determined by following the methods defined by the AOAC (*Association of Official Analytical Chemists*, 2016). Cholesterol concentration was determined by HPLC/PDA, on a HPLC Waters 2695 separation module, with Waters 2996 photodiode array detector. In order to determine the concentration of fatty acids, total lipids were extracted by a rapid extraction method, using solvents on the Dionex ASE 200. A homogenized sample, mixed with diatomaceous earth, was extracted with a mixture of hexane and isopropanol (60:40 v/v) in a 33 mL extraction cell at 100ºC and under nitrogen pressure of 10.3 MPa. The extract thus obtained was steamed in a nitrogen flow at 50°C until dry fat remains were obtained (*Spiric et al*., 2010). Fatty acids as methyl esters were detected by capillary gas chromatography with a flame ionization detector. A predetermined quantity of lipid extracts, obtained by the rapid extraction method, was dissolved in tert-butyl methyl ether. Fatty acids were converted to fatty acids methyl esters (FAME) with trimethylsulfonium hydroxide, according to the SRPS EN ISO 5509:2007 method. FAMEs were analysed with a GC-FID Shimadzu 2010 device (Kyoto, Japan) on a cyanopropyl-aryl column HP-88 (column length 100, internal diameter 0.25 mm, film thickness 0.20 µm). The injected volume was 1 µL. Temperatures of the injector and detector were 250ºC and 280ºC, respectively. Nitrogen was used as a carrier gas, 1.33 mL min^{-1}, with a split ratio of 1:50, while hydrogen and air were used as detector gases. The temperature of the column furnace was programmed to range between 120ºC and 230ºC. The total duration of analysis was 50.5 min. Methyl esters of acids were identified according to their retention times, which were compared with those of the mixture of methyl esters of fatty acids in the standard Supelco 37 Component FAME mix (*Spiric et al*., 2010).

Data was statistically analysed by the least squares method and the GLM procedure of the SAS 9.1.3 program package (SAS Inst. Inc. 2002–2003). Tukey’s test was used to compare the mean values of the genotypes when they were significantly different. Least squares of means (LSM) with respective standard errors of means (SEM) and significance levels are shown in the tables.

Results and discussion

Table 2 shows the live weights and carcass properties of Mangalitsa pigs reared in the free-range and conventional systems. The final live weight of Mangalitsa pigs and rearing system had a strong effect ($P < 0.001$) on the warm and cold carcasses weights. Simultaneously, conventionally reared pigs tended to be heavier. In their study, *Petrovic et al*. (2010) found differences in average masses of warm and cooled carcass sides between breeds.

In the current study, lower dressing percentages of the warm and cold carcasses were found in the free-range reared Mangalitsa pigs than in those fed conventionally ($P < 0.001$). However, the final live weight had a notable effect ($P < 0.01$) on carcass dressing percentage (Table 2). *Hoffman et al*. (2003), in their study, detailed warm (77.5%–77.7%) and cold (75.9%–76.4%) dressing percentages of pig carcasses. This is explained by the difference being possibly because the intake of grass fibre led to a better developed digestive system (mainly the large intestine) (*Hoffman et al*., 2003). In our study, the rearing system had no impact on the body length of the pigs, whereas live weight did ($P < 0.001$; Table 2). Differences in cooler shrink were not noted between the Mangalitsa pigs reared in the two rearing systems. *Anupam et al*. (2010) analysed the slaughter performance of Ghungroo, a native swine breed, and found that they had cooler shrink values of between 1.90% to 5.48%. In the current study, backfat thickness measurements at three control points was higher in conventional pigs (P1 = 3.73 mm, P2 =X3.05 mm, P3 = 3.90 mm) ($P < 0.001$); however, this was explained by the live weight of the pigs at slaughter and not by the effect of rearing system.

Our research showed that free-range reared system had no effect on accumulation of subcutaneous fat (Table 2).

Comparisons of the means for the chemical composition of the backfat derived from the free-range and conventionally reared Mangalitsa pigs are presented in Table 3. Significant differences ($P < 0.001$) were observed in the backfat water content depending on rearing system. Free-range reared Mangalitsa pig backfat contained a greater percentage of water than the backfat of the conventionally reared pigs. The percentage of water in backfat of Mangalitsa pigs kept in the conventional rearing system was 2.43% lower than in the outdoor pigs. The established value of water content in backfat of free-range reared Mangalitsa pigs (6.96%) was similar to the values of 6.53% (Cinta Senese pigs), 6.9% (Large White) and 7.76% (crossbreed pigs) found

Table 2. Comparison of the least squares mean ± (SEM) for the slaughter traits of free-range and conventionally reared Mangalitsa pigs

Trait	Rearing system		Significance of the influence [a]	
	Conv.[b] (n[c] = 12)	FR[d] (n = 12)	RS	LW
Starting live weight 70 day age (kg)	12.02 ± 1.02	12.18 ± 1.14	*	/
Average slaughter age (days)	397.57 ± 10.75	451.77 ± 10.75	***	/
Live weight (kg)	102.58 ± 3.85	98.33 ± 3.37	NS	/
Warm carcass weight (kg)	79.72 ± 0.41	76.41 ± 0.41	***	***
Cold carcass weight (kg)	77.82 ± 0.44	74.23 ± 0.44	***	***
Warm carcass DP[e] (%)	78.94 ± 0.51	75.91 ± 0.51	***	**
Cold carcass DP[e] (%)	77.31 ± 0.45	73.69 ± 0.45	***	**
Cooler shrink (%)	2.40 ± 0.22	2.85 ± 0.22	NS	NS
Carcass length (cm)	89.20 ± 0.61	89.22 ± 0.61	NS	***
Thickness of backfat P_1 (mm)	61.70 ± 1.48	57.97 ± 1.48	NS	***
Thickness of backfat P_2 (mm)	54.44 ± 1.91	51.39 ± 1.91	NS	***
Thickness of backfat P_3 (mm)	59.95 ± 1.83	56.05 ± 1.83	NS	***

Legend: [a] Significance level for rearing system (RS) and live weight (LW); [b] Conv. - Conventionally reared pigs; [c] n - number of samples; [d] FR - Free-range reared pigs; [e] DP: dressing percentage; P_1 - sacral point 1; P_2 - sacral point 2; P_3 - sacral point 3; NS — not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

by *Franci et al*. (2005). Pugliese *et al*. (2005) found 6.53% water in backfat of free-range Cinta Senese pigs and 5.34% in pigs kept in a conventional rearing system. In our study, the differences in main protein values between the two groups were significant ($P < 0.001$). Mangalitsa pigs reared conventionally had lower protein levels in the backfat than did free-range pigs. The live weight and the rearing system significantly influenced total fat content in the backfat (Table 3). In conventionally reared pigs, higher total fat content (3.27% higher) was determined than in the free-range group. The calculated fat/protein proportion was lower in backfat of the free-range reared Mangalitsa pigs compared with the conventionally reared group ($P < 0.001$).

In our study, the type of rearing system had an important effect on cholesterol content in the backfat of Mangalitsa pigs ($P < 0.05$; Table 4). The total cholesterol concentration of the backfat for pigs reared outdoors ranged between 31.40 mg kg^{-1} to 46.96 mg kg^{-1}, while the cholesterol concentration of conventionally raised Mangalitsa pigs ranged between 37.35 mg kg^{-1} to 55.80 mg kg^{-1}. *Csapó et al*. (2002) reported that the Mangalitsa pig fat had changeable cholesterol levels which ranged between 71 mg kg^{-1} and 109 mg kg^{-1}. There was no truth in reports demonstrating that the fat of Mangalitsa pigs contains less cholesterol than that of other types of fattening pig (*Csapó et al*. 2002). *Kovács* (2009) noted that the average cholesterol content in *m. longissimus dorsi* of Mangalitsa pigs was 52 mg kg^{-1}.

Table 4 presents the fatty acid profiles of the backfat in the Mangalitsa pigs reared free-range and conventionally. In both rearing systems, palmitic acid (C16:0), oleic acid (C18:1 n-9) and linoleic acid (C18:2 n-6) were the most common SFA, MUFA and PUFA, respectively, in the backfat of the pigs. The backfat of outdoor-reared Mangalitsa pigs contained less PUFA than pigs fed conventionally and reared indoors. These variations were created mostly by higher total n-6 PUFA levels in the backfat of the conventionally reared Mangalitsa pigs ($p < 0.001$), and likewise by slightly higher levels of total n-3 PUFA ($P < 0.05$) in free-range reared pigs. These caused lower n-6/n-3 ratios in the backfat of the free-range reared Mangalitsa pigs feeding on acorns and grass pasture ($P < 0.01$) (Table 4). Consequently, in spite of the fact that the n-6/n-3 ratios in pigs in our study were always higher than dietary guidelines (*British Nutrition Foundation*, 1994), free-rearing seems to be a beneficial way to reduce this ratio in porcine animals.

Our investigation is similar to research by *Hansen et al*. (2006), who showed that organic pigs had lower MUFA and higher PUFA levels than conventionally-reared pigs. In our research, the higher C18:2 n-6 concentrations in free-range Mangalitsa pigs contributed to their total PUFA concentration (8.27 ± 0.22) in comparison with that of the Mangalitsa pigs reared conventionally (9.19 ± 0.22). Higher MUFA levels were found in outdoor-reared Iberian pigs and this compound was also detected in intramuscular fat (*Andrés et al*., 2001). Table 4 presents the higher MUFA/SFA and PUFA/SFA ratio we ascertained for conventionally-reared pigs in comparison with the free-range Mangalitsa pigs. In contrast, the total MUFA/PUFA ratio of the backfat was not different between the two groups of Mangalitsa pigs. Differences in fatty acid profile between conventional and free-range Mangalitsa pigs are likely a consequence of the different feeds. The fatty acid profile of the intramuscular fat is affected by various factors; generally, diet appears to be one of the most important factors. The PUFA/SFA ratio is the second index normally used to estimate the nutritional value of fats, and the recommended value for human dietary needs is 0.45 (*Department of Health*, 1994). For *m. semimembranosus* from Mangalitsa pigs, values

Table 3. Comparison of the least squares mean ± (SEM) for the chemical composition and fat/protein ratio of backfat of free-range and conventionally reared Mangalitsa pigs

Item	**Rearing system**		**Significance of the influence** [a]	
	Conv.[b] **(n**[c] **= 12)**	**FR**[d] **(n = 12)**	**RS**	**LW**
Water content (%)	4.53 ± 0.25	6.96 ± 0.25	***	NS
Protein content (%)	1.45 ± 0.10	2.30 ± 0.10	***	NS
Total fat content (%)	94.02 ± 0.31	90.75 ± 0.31	***	*
Ash content (%)	0.06 ± 0.01	0.08 ± 0.01	NS	NS
Fat / protein ration e	67.09 ± 2.79	41.04 ± 2.79	***	NS

Legend: [a] Significance level for rearing system (RS) and live weight (LW); [b] Conv. - Conventionally reared pigs; [c] n - number of samples; [d] FR - Free-range reared pigs; [e] Fat / protein ratio was calculated. NS — not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 4. Comparison of the least squares mean ± (SEM) for the fatty acid composition (%) and cholesterol content (mg kg^{-1}) of backfat from free-range and conventionally reared Mangalitsa pigs

Item	Rearing system		Significance of the influence [a]	
	Conv.[b] (n[c] = 12)	FR[d] (n = 12)	RS	LW
C14:0	1.10 ± 0.03	1.38 ± 0.03	***	NS
C16:0	24.60 ± 0.26	27.49 ± 0.26	***	NS
C16:1	2.79 ± 0.15	3.47 ± 0.15	**	NS
C17:0	0.36 ± 0.02	0.38 ± 0.02	NS	NS
C17:1	0.22 ± 0.01	0.25 ± 0.01	*	***
C18:0	10.94 ± 0.29	12.67 ± 0.29	***	NS
C18:1 *cis*-9	49.64 ± 0.24	45.55 ± 0.24	***	NS
C18:1 *trans*-9	0.55 ± 0.03	0.56 ± 0.03	NS	NS
C18:*1 cis*-11	4.81 ± 0.15	4.77 ± 0.15	NS	NS
C18:2 cis n-6	8.22 ± 5.72	14.65 ± 5.72	NS	NS
C18:3 *n*-3	0.19 ± 0.02	0.41 ± 0.02	***	NS
C18:3 *n*-6	ND	ND	NS	NS
C20:0	0.21 ± 0.01	0.18 ± 0.01	*	NS
C20:1 *n*-9	0.99 ± 0.03	1.07 ± 0.03	NS	NS
C20:2 *n*-6	0.47 ± 0.06	0.56 ± 0.06	NS	NS
C20:3 *n*-3	0.04 ± 0.00	ND	***	NS
C20:3 *n*-6	0.39 ± 0.03	0.43 ± 0.03	NS	NS
C20:5 *n*-3	ND	ND	NS	NS
C22:1+C 20:4	0.15 ± 0.01	ND	***	NS
C22:5 *n*-3	ND	ND	NS	NS
C22:6 *n*-3	ND	ND	NS	NS
SFA	37.21 ± 0.36	42.11 ± 0.36	***	NS
MUFA	59.14 ± 0.32	55.66 ± 0.32	***	NS
PUFA	9.19 ± 0.22	8.27 ± 0.22	**	NS
USFA	68.34 ± 0.44	63.93 ± 0.44	***	NS
Total *n*-3 PUFA	0.37 ± 0.02	0.41 ± 0.02	NS	NS
Total *n*-6 PUFA	9.01 ± 0.21	7.87 ± 0.21	***	NS
MUFA/PUFA	6.48 ± 0.15	6.76 ± 0.15	NS	NS
MUFA/SFA	1.59 ± 0.02	1.32 ± 0.02	***	NS
PUFA/SFA	0.25 ± 0.01	0.20 ± 0.01	***	NS
USFA/SFA	1.84 ± 0.03	1.52 ± 0.03	***	NS
n-6/*n*-3 PUFA	25.23 ± 1.05	19.75 ± 1.05	**	NS
Cholesterol	45.75 ± 1.61	40.14 ± 1.61	*	NS

Legend: [a] Significance level for rearing system (RS) and live weight (LW); [b] Conv. - Conventionally reared pigs; [c] n - number of samples; [d] FR - Free-range reared pigs; ND - not detected; SFA - saturated fatty acids, MUFA - monounsaturated fatty acids, PUFA - polyunsaturated fatty acids, USFA - monounsaturated fatty acids + polyunsaturated fatty acids; Content of SFA, MUFA, PUFA — calculated from all detected acids; NS — not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

for PUFA = 14.94 and SFA = 32.43 (PUFA/SFA = 0.46), for *m. longisimuss dorsi* PUFA = 7.37, SFA = 36.58 (PUFA/SFA = 0.20) and for backfat PUFA = 13.90, SFA = 40.41 (PUFA/SFA = 0.34). Fats with low PUFA/SFA ratios are considered unfavourable, since they could cause increases in cholesterolaemia. Fat from, in particular, pasture-fed ruminants, normally contains PUFA/SFA in ratios below that recommended (*Sañudo et al*., 2000). *Nantapo et al*. (2014) examined the influence of genotype on fatty acid profiles of cow milk. They concluded that health-related ratios such as n-6/n-3 fatty acid ratios and PUFA/SFA ratios did not differ among bovine genotypes. However, indexes such as PUFA/SFA, based only on the chemical structure of fatty acids, may not be adequate to estimate nutritional value of fats, because they take into account the preposition that all SFA cause an increase in cholesterol, but they ignore the effects of MUFA.

Conclusions

Our study leads to the conclusion that free-range-reared Mangalitsa pigs had a lower backfat thickness than pigs reared in the conventional manner. In this study, the free-range rearing of Mangalitsa pigs produced higher protein, ash and water levels and lower total fat content and fat/protein ratios in the backfat, compared with conventionally housed and fed animals. Mangalitsa pigs reared in the conventional way produced backfat with higher MUFA, PUFA and USFA levels, higher concentrations of PUFA n-6, plus higher PUFA/SFA and n-6/n-3 ratios in the backfat in comparison with Mangalitsa pigs when reared free-range. The choice of rearing system had an important influence on cholesterol levels in Mangalitsa pig backfat. These potential applications to affect fatty acid composition of pork and products thereof could be of great interest, considering the increase in consumer concerns about food origin, safety and nutritional value. Accordingly, animal feeding outdoors, on pasture, appears to be an interesting strategy to improve the healthful image of (organic) pork from the human health point of view.

Uticaj sistema gajenja na kvalitat trupa, hemijski sastav i sadržaj masnih kiselina leđne slanine Mangulica

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A p s t r a k t: Cilj ovog rada bio je uticaj dva sistema gajenja (konvencionalni i slobodni uzgoj) na karakteristike trupa, kao i na sadržaj holesterola, hemijski sastav i sadržaj masnih kiselina leđne masnoće Mangulica. U zavisnosti od sistema gajenja i posmatrane telesne mase, utvrđene su značajne razlike u masi hladnih i toplih polutki Mangalica. Maksimalni ukupni holesterol u masnoći svinja koje se gajene u slobodnom sistemu uzgoja bio je 46,96 mg kg^{-1}, dok je maksimalni ukupni holesterol u masnoći konvencionalno uzgajanih Mangalica bio 55,80 mg kg^{-1}. Masnoća Mangalica koja je gajena u slobodnom sistemu imala je manji sadržaj PUFA n-6 i veći sadržaj PUFA n-3. Odnos PUFA / SFA bio je izuzetno različit kod svinja koje su gajane u dva sistema, dok je odnos MUFA / SFA bio manji kod svinja koje su gajane u slobodnom sistemu. Na osnovu ovih rezultata, izbor sistema za uzgoj svinja mogao bi da utiče na hemijska svojstva i karakteristike trupa Mangalica.

Ključne reči: *sistem gajenja; autohtona rasa; osobine trupa; leđna slanina; holesterol; masne kiseline.*

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