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Physiochemical Properties and Oxidation Status of Pork from Three Rearing System (Organic, Conventional and Traditional)

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Abstract: The aim of the study was to evaluate the impact of different rearing systems (organic, conventional and traditional) on the physicochemical properties and oxidation states of pork meat. Samples (*M.biceps femoris*) were obtained from producers directly 3 days after slaughtering. Chemical composition (dry matter, protein, collagen, fat, ash), colour (L*, a*, b*) and oxidation state (Thiobarbituric acid reactive substances -TBARS, free fatty acid -FFA and antioxidant capacity-2,2-diphenyl-1-picrylhydrazyl) of the meat samples were determined. The results indicated that the rearing system affects most of the evaluated parameters. The significant difference ($P < 0.05$) was observed in colour parameter L* and b*, where the conventional pork was darker and the organic pork yellower. Total protein content in meat of conventional pigs was higher, whereas the fat content in the meat of organically reared pigs was higher than the meat of pigs from both other rearing systems. Organic pork was more susceptible to oxidation process due to its higher TBARS and FFA values and lower antioxidant capacity, which may result in inferior technological properties of meat.

Keywords: ecological system; pork composition; TBARS; antioxidant

1. Introduction

The traditional rearing methods of the past allowed pigs to range freely during the day and sleep in a spacious pigsty at night. In recent decades, such old traditional method is replaced by intensive rearing (conventional) system in which the pigs continuously confined in restricted, stimulus-poor space due to ergonomically, economic and health reasons [1]. Intensive breeding (conventional) system is under criticism due to poor animal welfare where the confined pigs in stalls are no longer able to express their natural species-specific behaviours completely. Thus, not only whole food safety and sensory quality of pork, but also life quality of pigs rearing systems have been very important to consumers and has become a major point of concern as well [2]. Furthermore, it is a common belief among consumers that the quality of pork from pigs raised under extensive systems is better [3]. This led to increased interest in alternative rearing systems such as outdoor, free range and organic production systems. Organic farming is the most regulated alternative production systems, which provide the minimum level of environmental sustainability and welfare for breeding animals [4]. Rules of organic production systems including housing conditions (indoor and outside area), feeding, age and genotype of animals are defined in EU legislation [5]. The core point of rearing system differences is availability of outdoor area for animals. Roles of outdoor area can be summed up mainly by the pig's physical activity, better animal welfare and feed quality (ingestion of herbage and soil at pasture) which could be reflected on quality and quantity of meat [6]. Another factor that can be play a role through rearing system on the production properties and meat quality is pigs genotype. Local breeds of pigs are considered to be most suitable for outdoor production system. On the other side, such local breeds are characterised by inferior carcass qualities, low feed consumption efficiency and growth intensity in comparison with specialised breeds that are used by conventional systems [7]. Rearing conditions of pigs under alternative systems (free range and organic systems, outdoor access) increases energy expenditure for physical activity and thermoregulation, which decrease growth rate, but improves some properties of meat quality such as the production of lean meat and higher meat oxidative stability [8]. In contrast, other authors indicate that higher intramuscular of fat and unsaturated fatty acid composition in organic pork enhanced lipid oxidation resulting in inferior technological meat quality [9–11]. However, many studies of pig rearing system effects on the quantity and quality including the oxidation status of pork have yielded widely differing results and conclusions [6,8,12–14]. The contradictory conclusions could be attributed to large differences in the design of the rearing systems [15].

The aim of the study is another attempt toward the clarification how three pigs rearing systems (organic, conventional and traditional) impact physicochemical properties and oxidation status of pork meat.

2. Materials and Methods

2.1. Rearing conditions of animals and samples preparation

Samples of meat were obtained directly from breeders at their slaughterhouses. The samples of organic pork were from Biofarma Sasov (Sasov 2, 58601 Jihlava, Czech Republic), conventional pork from slaughterhouse Šebkovice, s.r.o. (Šebkovice, 675 45, Czech Republic) and traditional pork were from Farma rodiny Němcovy (Netín 78, 594 44 Radostín nad Oslavou, Czech Republic). Information about age and weight of pigs at slaughter as well as the genotypes of such pigs are explained in the Table 1.

Organic pig farming: the piglet after the birth stay together with their mothers till 35 days of age, then with their mother were moved to the stables. In such stables there are usually 5 to 6 sows with piglets and always 1 boar. piglets feeding is the milk of sow that provides them nutrition and protection against diseases. The animals had constant access to outdoor for provide a natural life processes as in nature. Weaning occurs at 3 months of age of the piglets. After weaning, the piglets remain in the same environment, in the same stable as before. The period of feeding was 7 months. Feed rations were balanced, full-value, composed exclusively of organic feed and the permitted amount of permitted conventional feed - no extracted meal, no meat-and-bone meal, growth promoters, hormonal substances, synthetic amino acids, antibiotics, etc. Ecological slaughter is ensured by slaughterhouses directly on the farm. During all movements within the farm, the pigs walk on their own and are not stressed by transport, including journey to slaughterhouse. The entire breeding of livestock on farm is based on the greatest possible animal welfare and their most natural living conditions.

Conventional pig farming: Weaning at the earliest at 3 weeks of age, animals were divided into groups according to sex and breeding plan immediately after weaning. pigs are in permanently closed stables with controlled air conditioning. Minimum pen area / 1 animal was - up to 50 kg 0.40 m2, - up to 85 kg 0.55 m2, - up to 110 kg 0.70 m2. The information about age and live weight of pigs at slaughter as well as the genotype of animals is explained in table 1.

Traditional pig farming: The farm confirmed that rearing system is based on the old tradition of the Czech countryside. The farm combined modern technology with rural experience and skills. The farm use pig from genotype Prestice Black-Pie, which is not suitable for conventional system and in large farms. Such genotype of pig is appropriate for use in small farms and organic system production. Growth period is extended to 7 months; pigs receive a tailor-made feed ration without use of GMO feed.

Samples preparation: A total of 30 samples from three different rearing system were used for analysis. 10 meat samples of about 150 g from M. biceps femoris were taken from each farm. The meat samples were transport in cold atmosphere (around 4 °C) to the university of veterinary sciences Brno were the analyses conducted. Physico-chemical and oxidative analysis was performed 3 days after slaughter. The samples for antioxidant capacity analysis was stored (in vacuum atmosphere) in a freezer at -70 ° C until the day of analysis.

Table 1. characterises of pigs from organic, conventional and traditional rearing system.

rearing system	age (months)	live weight (kg)	genotype
organic	7	80	Prestice Black-Pie (meat-bacon breed)
conventional	6	110-120	Czech Improved White Pigs (meat type)
traditional	7	90–100	Prestice Black-Pie

2.2. Color evaluation

The color indicators (lightness / L * /; redness / a * /; yellowness / b * /) of the muscle surface were measured according to the CIE L * a * b * system, by using spectrophotometer instrument CM-5 (Konica Minolta Sensing, Inc., Japan). The program SpectraMagic NX Color Data Software was used to calculate the variables, the mean and the standard deviation of five measurements for each sample was recorded.

2.3. Chemical composition

The meat samples were minced in order to be used for assay of chemical composition. The amount of dry matter was determined gravimetrically by drying the sample for 24 hours at 103 ± 2 ° C according to ISO 1442 [16]. Determination of total protein was performed by using a Kjeltec 2300 (FOSS Analytical AB, Sweden) based on the amount of organically bound nitrogen. A conversion factor of 6.25 was used. The determination was performed according to ISO 937 [17]. Collagen was calculated (coefficient f = 8), using the amino acid hydroxyproline. Hydroxyproline was determined by spectrophotometer via measuring absorbance at 550 nm on a GENESYSTM6 instrument (Thermo Electron Corporation, USA). The method was performed according to SOP [18]. Determination of fat was performed analytically using SOXTEC 2055 (FOSS Analytical AB, Sweden). Petroleum ether was used as the solvent. The analysis was performed according to ISO 1443 [19]. Carbohydrates were mathematically calculated using the formula: Carbohydrates = dry matter - (total protein + fat + ash). The ash was determined gravimetrically by burning the sample in a muffle oven (Elektro LM 212.11, Germany), at 550 °C until the black particles in the ash completely disappear according to ISO 936 [20].

2.4. Oxidation status evaluation

Thiobarbituric acid reactive substances (TBARS): The extent of lipid oxidation was evaluated and determined as TBARS. 10 g of minced meat samples was homogenized for 2 minutes with 95.7 ml of distilled water and 2.5 ml of 4 M HCl. the samples were distilled until a 50 ml distillate was obtained. 5 ml of 15% trichloroacetic acid, 0.375% thiobarbituric acid reagent was added 5 ml of distillate and the mixture was heated in a boiling water bath for 35 minutes. the samples left to cool then absorbance of the samples was measured at 532 nm by spectrophotometer, against an appropriate blank. TBARS values were obtained by multiplying the absorbance value by 7.8. Oxidation products were quantified as malondialdehyde equivalents (MDA mg.kg-1) [21]. Free fatty acids (FFA): its determination was performed by the titration method according to CSN EN ISO 660 (588756) [22], and were expressed as the percentage of total fat as oleic acid. Antioxidant capacity: The 2,2-diphenyl-1-picrylhydrazyl (DPPH) method was used for the determination of the antioxidant capacity [23]. Samples preparation was according to Jung et al. [24] by homogenising of 3 g of sample (minced meat) with 15 ml of 5% trichloroacetic acid, then 10 ml of chloroform was added. DPPH in methanol (0.025 g/l) was dissolved in order to prepared fresh solution of radical stock. such fresh solution of DPPH was measured by spectrophotometer against a blank at 515 nm, and the obtained result (absorbance value) was recorded (A0). Sample of meat extract (0.2 ml) was added to DPPH solution (3.8 ml) and the absorbance was measured (A10) after 10 min. The percentage of inhibition for DPPH radical was calculated according to the following formula:

% inhibition = (A0 – A10/A0) × 100
where A0 was the absorbance of the control at time = 0 min;
A10 the absorbance of the antioxidant at time = 10 min.

2.5. Statistical analyses

Mean and standard deviation (mean ± SD) were calculated using Microsoft Office Excel 2017. Significance ($P < 0.05$) was assessed by analysis of variance (ANOVA) with Tukey's test for differences between breeds. Overall differences among samples were checked by principal component analysis (PCA). SPSS 20 statistical software (IBM Corporation, Armonk, USA) was used.

3. Results

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

3.1. Color

The results of the color data are shown in Table 2. The results showed that the meat of organically and traditionally raised pigs was significantly ($P < 0.05$) lighter in color (higher L* values) than conventionally raised pork. The redness indicator (a*) was lower (not statistically significant) in traditional pork than in organic and conventional pork. Pork from organic pigs was significantly ($P < 0.05$) yellower (higher b* values) than conventional and conventional pork.

Table 2. color indicators of pork (mean ± SD) from organic, conventional and traditional rearing system.

parameters	rearing systems			P
	organic	conventional	traditional	
L*	54.39 ± 3.71^{a}	46.30 ± 2.35^{b}	51.69 ± 3.01^{a}	*
a*	4.90 ± 1.93	4.61 ± 1.38	3.57 ± 1.17	NS
b*	13.87 ± 1.09^{a}	11.36 ± 0.81^{b}	11.81 ± 1.15^{b}	*

Values in the same row with different superscripts $^{a,\,b}$ are significantly different among organic, conventional and traditional pork.

3.2. Chemical composition

Chemical composition results are explained in Table 3. Pork from conventional system contained more ($P < 0.05$) dietary fiber than traditional pork, whereas no significant differences were found between organic pork and both conventional and traditional pork. The total protein content of organic and traditional pork was significantly lower ($P < 0.05$) than that of conventional pork. The results showed that organic meat had a higher collagen content (not statistically significant). The fat content of organic pork was significantly higher ($P < 0.05$) than that of conventional and traditional pork. Traditional pork contained less carbohydrate ($P < 0.05$) than organic and conventional pork.

Table 3. chemical composition of pork (mean ± SD) from organic, conventional and traditional rearing system.

parameters [%]	rearing systems			P
	organic	conventional	traditional	
dry matter	25.13 ± 1.41^{ab}	25.48 ± 1.61^{a}	23.73 ± 0.43^{b}	*
total protein	20.36 ± 1.06^{b}	22.23 ± 0.76^{a}	21.21 ± 0.52^{b}	*
collagen	0.62 ± 0.23	0.59 ± 0.19	0.52 ± 0.09	NS

fat	2.81 ± 1.37[a]	1.43 ± 0.97[b]	0.37 ± 0.12[b]	*
carbohydrates	1.85 ± 0.78[a]	1.45 ± 0.57[a]	0.77 ± 0.44[b]	*
ash	1.37 ± 0.29	1.18 ± 0.07	1.38 ± 0.17	NS

Values in the same row with different superscripts [a, b] are significantly different among organic, conventional and traditional pork.

3.3. Oxidation status

The results of oxidative status (TBARS, free fatty acids, and antioxidant capacity) are shown in Table 4. TBARS expressing secondary oxidation of organic and conventional meat was higher ($P < 0.05$) than conventional meat. Free fatty acids in organic pork were highest, followed by traditional and conventional pork. The antioxidant capacity of organic pork was lower ($P < 0.05$) than conventional and traditional pork.

Table 4. oxidation status of pork (mean ± SD) from organic, conventional and traditional rearing system.

parameters	rearing systems			P
	organic	conventional	traditional	
TBARS [mg/kg]	1.24 ± 0.54[a]	1.00 ± 0.47[a]	0.41 ± 0.16[b]	*
free fatty acids	1.15 ± 0.17[a]	0.58 ± 0.10[c]	0.76 ± 0.18[b]	*
antioxidants capacity	26.42 ± 1.98[b]	28.24 ± 2.05[a]	27.50 ± 1.30[a]	*

Values in the same row with different superscripts [a, b, c] are significantly different among organic, conventional and traditional pork.

Principal component analysis of all measured parameters showed no differences ($p>0.05$) between three examined rearing systems (Figure 1).

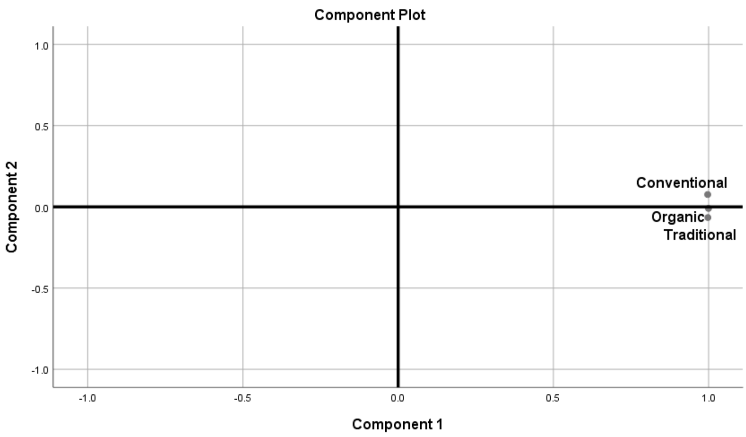

Figure 1. Principal component analysis of all samples' parameters included in the research (origin, conventional and traditional rearing systems.

4. Discussion

The growth rate of organic and traditionally raised pigs was lower compared to conventionally raised pigs. Pigs from conventional rearing reached higher weight (110-120 kg) with shorter rearing period (6 months) (Table 1). The slow growth of organically raised pigs could be due to higher energy requirements for activity and thermoregulation. Access to outdoor exercise is a basic principle of organic farming, and free-range housing provides animals with the opportunity for greater physical activity than in the conventional system. Conventional pigs are kept in groups in much smaller spaces, without access to outdoor areas, and may have higher energy content in their diets, resulting

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in higher daily gains [13,15]. Pig genotype also plays an important role in production traits (live weight and growth rate). Commercial hybrids are often used in intensive rearing systems (conventional) because of their fast growth rate and adaptability to housing systems with limited space. In contrast, alternative rearing systems such as organic and free-range prefer slow-growing pig strains with high adaptability to different environmental conditions [8,25].

4.1. Color

Color is an important attribute of meat quality for consumers. The results of meat brightness (L* value) in our work agree with those of Tomažin et al. [26] that meat from organic pigs was brighter than that from conventional pigs. In this study [26], it was found that the meat from organic pigs had higher CIE L*, a*, and b* values than the meat from conventionally raised pigs. In contrast, Olsson and Pickova [27] indicated that the meat from organically raised pigs was darker/lighter in color, but the study acknowledged that the evidence for this was inconclusive. Although redness scores (a*) of organic meat were the highest, the difference was not significant ($P > 0.05$). The greater yellowing of organic meat could be due to the feeding of pigs in the organic system and, in particular, the intake of grass in the free-range system. Organically raised pigs consume a greater amount of vegetable feed containing carotenoid pigments [28,29]. The fat content is also related to the yellow color of the meat. Our result showed that the meat from organic pigs had the highest values in fat content, which could be the reason for the more yellowish color. The yellowish color of the meat is also due to the high intramuscular lipid content and the incorporation of lipophilic pigments [30].

4.2. Chemical composition

The effects of pig housing system on the chemical composition of pork have not been consistent in published studies [27]. In the present study, significant differences in dry matter, protein, fat, and carbohydrate content were found in the meat of pigs from different housing systems. In contrast, no significant differences were found in dry matter, protein, fat, and ash content in meat from pigs raised in free-range or conventional systems by Hoffman et al. [31]. The higher protein content in conventional pork and the higher fat content in organic pork than the analysed meat from the other two housing systems in our study contradicts previous studies [32–34]. However, higher intramuscular fat content was also found in organic pork by Sundrum et al. [10]. The collagen content of organic pork tended to be higher (not significant, $P > 0.05$) than that of meat from conventionally and traditionally raised pigs, which could be attributed to the motor activity of the animals [15]. The physical activity of organically raised animals primarily affects the metabolic state of the muscles at slaughter, whereas it has a limited effect on the chemical composition of the meat. The influence of the husbandry system on the chemical composition of the meat is often due to differences in feed composition and intake, as well as the energy required to maintain the animals [27]. The energy content of the feed according to organic standards, combined with a mild climate during animal production, could be the reason for the thicker meat of the organic pigs in this work. The higher fat content of organic pork may also be attributed to the genotype of the pigs used for breeding. In contrast, the genotype of the pig used in the conventional system is a meat type and the fat content is not as high, even at a higher slaughter weight.

4.3. Oxidation status

Lipid oxidation is one of the main causes of meat deterioration, leading to the formation of compounds that are potentially serious for human health. The initiation and propagation of lipid oxidation may occur due to an imbalance in the balance between pro- and antioxidant substances that occurs during the conversion of muscle into edible meat after slaughter [36]. The higher TBARS levels and lower antioxidant capacity of organic pork in our study may be due to the inability to maintain such a balance between pro- and antioxidant factors. Tomažin et al. [26] indicated that the higher TBARS levels in meat from organic pigs may be related to the lack of vitamin E (lipid oxidation inhibitor) for antioxidant protection of PUFA. The higher TBARS levels and lower antioxidant (vitamin E) content in meat from organically raised pigs corresponded to the higher intake of polyunsaturated fatty acids reflected in the meat [13]. Free fatty acids may have a pro-oxidant effect on lipid substances, which have a catalytic effect for the carboxyl group in the formation of free radicals during the decomposition of hydroperoxides [36,37]. According to the results of FFA in our study, meat from organic pigs was more susceptible to lipid oxidation than meat from traditional and conventional pigs. High oxidative stability of the meat required low TBARS and FFA values [37,38]. However, the higher lipid oxidation was observed in organic meat by Martino et al. [8] and Nilzén et al. [11]. The lower antioxidant capacity observed in meat from organic pigs in this study may be due to its involvement in controlling oxidation processes in the body, thus depleting its reserves in the meat. Kouba et al [39] found that the low level of antioxidants (vitamin E) in pig tissues containing high concentrations of PUFA was due to the use of antioxidants to control oxidative processes. However, the most important factors affecting oxidative stability are the diet, sex, and breed of the animal, as well as the storage temperature and fat composition of the meat [37,38].

5. Conclusions

The results of the study confirmed significant differences in physiochemical properties and oxidation status of pork from organic, conventional and traditional farming. The results of the color indicators showed that the conventional pork was darker and the organic pork was more yellow. The meat from conventionally raised pigs had higher protein content, while the meat from organically raised pigs contained higher fat content. The study found that organic pork was more susceptible to oxidation than conventional and heritage pork. The study did not cover all husbandry conditions, such as the dietary composition of pigs in each husbandry system, which could play an important role in the results of the study. However, only the stated information (about housing conditions) was obtained from the breeders in this study. Further studies are needed to consider these aspects.

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