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Quality traits of pork from cross-bred local pigs reared under free-range and semi-intensive systems

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Abstract

This study was conducted to evaluate meat quality traits, proximate composition, fatty acid profile and sensory attributes of pork produced under free-range and semi-intensive pig rearing systems. *Longissimus dorsi* muscles from pork carcasses were taken just after the slaughtering of finishing pigs reared under semi-intensive and free-range systems to test the meat quality parameters (pH, color, water holding capacity, and cooking loss), proximate composition (moisture, protein, fat, and ash) and fatty acid profile. Furthermore, the organoleptic properties were evaluated using 30 untrained panelists. The results revealed that the system of rearing did not affect ($p > 0.05$) the proximate composition, water holding capacity, color, pH and cooking loss of pork along with the fatty acid composition except for vaccenic acid ($p < 0.05$). The monounsaturated fatty acid (MUFA) content was affected ($p < 0.05$) by the rearing system while no effects were observed on the unsaturated fatty acid: saturated fatty acid ratio and omega-six to omega-three fatty acids ratios ($p > 0.05$). No difference was observed ($p > 0.05$) concerning the sensory attributes although pork obtained from the free-range system had the highest scores. In conclusion, the system of rearing did not show a significant effect on the meat quality parameters, composition and sensory attributes of pork obtained from cross-bred pigs.

Keywords: cross-bred, free-range, *longissimus dorsi* muscle, meat quality traits, semi-intensive

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Introduction

Pork has been served as an important source of high-quality animal proteins, essential minerals and vitamins in the human diet. Recently, the commercial interest in pork products originating from natural animal production systems has been increased due to consumer concern for welfare. Many studies have revealed that free-range pork has superior taste compared to pork produced in intensive conditions and has health benefits for humans due to the increased total n-3 and n-6 polyunsaturated fatty acids (PUFA) of neutral lipids and total n-3 of polar lipids and with these advantages, the outdoor/free-range pig rearing has increased (Miao et al., 2004).

Meat quality parameters such as water holding capacity, color, pH, texture as well as sensory attributes can be varied according to the breed, species, sex, age, feed, environmental conditions and physical activities. Based on these conditions, fatty acids and other components also can be changed. The variation in fat and fatty acid profile in meat has a more significant effect on meat quality (Choi et al., 2014; Kim et al., 2017). The influence of the rearing system on the animal performance, carcass and meat is the result of the interactive effects among available infrastructure facilities (type of floor, space, environmental temperature and physical activity), feeding level and genotype used in the production systems (Lebret and Mourot, 1998). The higher amounted unsaturated lipid profile of meat produced in a system that resulted by feeds may good, concerning the nutritional meat quality when compared to conventional total confinement (Bee et al., 2004). Further, meat fatty acid composition is of great interest because of its implications for human health. High intake of saturated fatty acid causes elevated plasma cholesterol, which contributes to cardiovascular disease (Siri-Tarino et al., 2010). Polyunsaturated fatty acid and monounsaturated fatty acid increase hepatic low-density lipoprotein which will affect the decreasing the circulating concentration of low-density lipoprotein cholesterol. Low content of intramuscular fat (low marbling) is believed to negatively impact pork flavor, thus producing healthier pork without compromising consumer acceptable palatability is important (Cannata et al., 2009).

The rearing systems of pigs existed in different forms and the contribution to the total local pork production vary. In some European countries, particularly the UK and France, there are significant numbers of outdoor herds contributing to conventional pig meat supplies (Edwards, 2005). Nevertheless, the Sri Lankan pork market depends on the pigs comes from both free-range and semi-intensive systems and pork produced under the free-range system play a key role. The quality of pork produced under different rearing systems have been well documented where pork production is high globally (Lebret and Mourot, 1998; Hoffman et al., 2003; Lebret, 2008). However, there are no research has been conducted to evaluate the quality of pork produced under different rearing conditions in Sri Lanka. Further, the quality assessment of the pork is important for consumer health and this has been a good source of income for households living in the pig belt in Sri Lanka. Thus, the current study was conducted to evaluate meat quality traits, proximate composition, the fatty acid profile and sensory attributes of pork produced under free-range and semi-intensive pig rearing systems.

Materials and methods

Sample collection

A total of 8 pork carcasses (cross-bred pig); 4 for each system, were obtained from pigs reared under semi-intensive and free-range systems. Four (04) *Longissimus dorsi* muscle samples were collected representing each rearing system. Samples were properly packed and sealed in polyethylene bags after the removal of the fat layer. They were stored under refrigerated conditions for 24 h to facilitate the rigor mortis. Then the samples were transported to the university laboratory under freezing conditions (-18℃) and they were stored under chilling conditions (-4℃) until further analysis.

Proximate analysis

Six meat samples from each pig carcass, which were collected from free-range and semi-intensively reared were analyzed for moisture, fat, protein and ash contents using AOAC (2000) methods. Briefly, the protein was quantified using the micro-Kjeldahl method (method 954.01 of AOAC, 2000) with a block digester and nitrogen distiller. Fat content was determined according to the Soxhlet method (method 920.39 of AOAC, 2000) using a Soxhlet extractor (VELP Scientifica SER 148/6 Solvent Extractor, Italy). Moisture content was determined in an oven at a temperature of 105℃ until a constant sample weight was obtained (method 950.46 of AOAC, 2000). Determination of ash was performed by carbonization and incineration of the samples in a muffle furnace at a temperature of 550℃ (method 920.153 of AOAC, 2000).

Meat quality parameters

The pH of meat samples was measured with 1 g of minced meat from each sample which was put into falcon tubes and mixed with 9 mL of distilled water and homogenized using a vortex mixer (VM-96B, Hansol Tech, Seoul, Korea) at 2,000 rpm for 30 seconds. Then all samples were filtered using filter papers (Whatmann® No. 1, Maidstone, UK) and the filtrate was used to evaluate pH using a calibrated pH meter (PH700, Eutech instrument, Ayer Rajah Crescent, Singapore). The mean value of two repeated measurements from each sample was taken.

Cooking loss measurement was determined as per the standard method; a 30 g of thick slice cut from *Longissimus* muscle was placed in polypropylene bags and then cooked for 30 minutes at 80℃ in the water bath (LWB-IIID, Daihanlabtech Co., LTD., Namyangju, Korea). Then samples were cooled to room temperature. Cooking loss was determined by calculating the weight loss during cooking as a percentage of the weight before cooking.

Water Holding Capacity (WHC) was measured using *Longissimus* muscle samples (2 g ± 0.01) from each sample were put on a filter paper (Whatmann® No. 04, Maidstone, UK) and covered with the same filter paper. They were left under a 10 kg weight for 5 minutes. The final sample weight was taken and used to calculate WHC as per the following equation. The mean of triplicates was taken for each sample.

$$WHC = 100 - [(W_i - W_f/W_i) \times 100] \quad (1)$$

W_i: Initial weight of the sample

W_f: Final weight of the sample

The color of the meat samples was determined with a Minolta CR410 colorimeter (Konica Minolta, Osaka, Japan) which was calibrated against a white reference tile, used to evaluate the color and lightness (CIE L*) at the three places of *Longissimus dorci* muscle of different samples according to the method described by Zhang et al. (2018). The values of lightness (CIE L*), redness (CIE a*) and yellowness (CIE b*) were measured in fresh muscle as well as the minced meat samples. Average values of each sample were used to analyze the data.

Fatty acid composition

The fatty acid composition of muscle samples was determined using the technique given by Bligh and Dyer (1959). Fatty acid profiles were determined using capillary gas chromatography (GC-2014 Shimadzu, Kyoto, Japan).

Sensory evaluation

Fresh meat samples from each treatment were cut into 2 cm × 2 cm cubes and fried in ceramic pans for 3 minutes. Samples were labelled with random three-digit numbers and evaluated using 30 untrained panellists for appearance, color, odor, taste, juiciness, tenderness and, overall acceptability using the 5-point hedonic scale (1 = dislike very much, 3 = neither like nor dislike, 5 = like very much).

Statistical analysis

All data were analyzed for standard errors, means and analysis of variances using t-test in Statistical Analysis System (SAS, 2013), version 9.1. Software while data from the sensory analysis were analyzed using Friedmann non-parametric test.

Results and Discussion

The proximate composition of pork obtained from cross-bred pigs reared under semi-intensive and free-range systems is presented in Table 1. All compositional characteristics (i.e., moisture, protein, fat and ash content) were not affected by the system of rearing ($p > 0.05$) (see Table 1). Cross-bred swine reared in the free-range system showed numerically higher protein content (28.40%) while cross-bred swine reared under semi-intensive system showed numerically higher moisture (69.30%) and ash (1.15%) contents. However, there was no significant difference amongst the compositional variation ($p > 0.05$). Several studies have been reported that pigs reared outdoors had a higher amount of lean meat and a lower fat ratio than pigs reared in confinement (Enfält et al., 1997; Sather et al., 1997; Heyer et al., 2006). However, Van der Wal et al. (1993) reported that the pigs raised outdoors tended to have more subcutaneous fat and a lower amount of lean meat when comparing carcasses with the same weight. Besides, Guy et al. (2002) and Edwards (2005) have shown that the proportion of the day spent active does not appear to be greatly increased in outdoor conditions. Further, the effect of exercise is unlikely to be important for primary meat quality differences between indoor and outdoor pigs, since forced exercise on a treadmill had no influence on muscle characteristics at slaughter or sensory qualities (Araújo et al., 2011). Similarly, results from the present study are in agreement with the existing findings on the proximate composition of muscle, where was not affected by moderately intense exercise or spontaneous physical activity of an animal (Gentry et al., 2002).

The meat quality parameters of pork obtained from cross-bred pigs reared under semi-intensive and free-range systems are presented in Table 2. pH, water holding capacity (WHC) and cooking loss (CL) of the pork were not affected ($p > 0.05$) by the rearing system (see Table 2). Pork obtained from crossbred pigs reared under the free-range system showed markedly higher pH (5.96) and WHC (82.77%) while cooking loss (30.95%) showed the least value compared to the pork obtained from the semi-intensive rearing system (see Table 2). These slight changes in observations of WHC and cooking loss might be due to the changes in the composition of the muscle, especially the pH. Higher pH is associated with better WHC and darker color which the results of the present study also numerically ($p > 0.05$) in accordance with. However, there is no difference among the pork obtained from both rearing systems in terms of meat quality parameters ($p > 0.05$). A previous study has evident that exercise did not affect muscle pH, but exercise decreased backfat thickness and sensory panel tenderness scores (Lewis et al., 1989). Furthermore, Araújo et al. (2011) reported that the pork obtained from outdoor reared swine was not different ($p > 0.05$) from that obtained from intensively reared swine in terms of color, cooking loss, water holding capacity and pH, which is in agreement with the present study results.

Table 1. Proximate composition of pork (*Longissimus dorsi* muscle) obtained from semi-intensive and free-range rearing systems.

Parameter (%)	Carcass samples		SEM	p-value
	SI	FR		
Moisture	69.30	68.43	0.56	0.20
Protein	27.55	28.40	1.48	0.31
Fat	5.87	5.85	0.20	2.05
Ash	1.15	1.01	0.05	4.36

SI, semi-intensive; FR, free-range; SEM, standard error of mean.

Table 2. Meat quality parameters of pork (*Longissimus dorsi* muscle) obtained from semi-intensive and free-range rearing systems.

Parameter	Fresh meat samples		SEM	p-value
	SI	FR		
pH	5.89	5.96	0.16	0.09
Water holding capacity (%)	79.33	82.77	2.80	0.75
Cooking loss (%)	32.17	30.95	2.81	0.06
Color values				
CIE L*	53.27	51.90	3.84	0.12
CIE a*	16.05	15.87	0.48	0.23
CIE b*	11.58	10.16	1.63	0.43

SI, semi-intensive; FR, free-range; SEM, standard error of mean; CIE, Commission Internationale de l'Eclairage; L*, lightness; a*, redness; b*, yellowness.

Pork obtained from the crossbred pigs reared under the free-range system showed no difference between CIE L*, a*, b* values than the meat obtained from the semi-intensive system ($p > 0.05$) (Table 2). However, pork obtained from the semi-intensive rearing system showed substantially higher lightness, redness and yellowness when compared with that from the free-range system (see Table 2). This may be due to the genotype variation, variation in feed available in each system (Rosenvold and Andersen, 2003). As revealed by the findings of Essén-Gustavsson et al. (1992), the fiber types and fiber morphology could be other possible reasons for the slight variation in color values of our results. It is found that the high ultimate pH alters the light absorption characteristics of the myoglobin, the meat surfaces give a darker red color (Weiss et al., 1975). In the present study results for pH have slightly varied around the normal pH of the fresh meat (i.e., 5.5), hence the color of the pork is in an acceptable range. Moreover, the study by Bee et al. (2004) has been reported that pigs reared outdoor have darker meat color, even though all of the pork in this study were shown similar color.

The comparison between fatty acid composition of pork obtained from cross-bred pigs reared under semi-intensive and free-range systems is presented in Table 3. The meat obtained from the cross-bred pigs reared under the free-range system did not show a difference ($p > 0.05$) between fatty acids except vaccenic acid ($p < 0.05$) compared to the pork obtained from the semi-intensive system. However, Stearic (C18:0) and Eicosapentaenoic (C20:5(n-3)) fatty acid contents were numerically higher in pork obtained from the free-range pigs while the Vaccenic (C18:1(n-7)) acid showed a higher amount than in the pork obtained from the semi-intensive rearing system ($p < 0.05$).

Not only the content of fatty acid but also the fatty acid profile present in it affects the carcass quality of pigs. According to previous studies, the growing and finishing pigs in outdoor systems with pasture, showed better meat quality than the confined system, introducing more favourable characteristics to human health (Weiss et al., 1975; Galián et al., 2008). It was reported that there were high C18:1, C18:2 and C18:3 in the fatty acid composition of intra-muscle fat in animals reared outdoors (Galián et al., 2008). Moreover, the level of C18:3 in intra-muscle fat was higher in animals fed forage, than in animals reared outdoors without access to controlled feeding (Galián et al., 2008; Parunović et al., 2012). A study conducted on the effect of rearing of wild boar in three systems of rearing on fatty acid composition has revealed that pork samples from extensively and intensively fed groups were more favourable. The samples from all wild boar groups contained more fatty acid than those from domestic pigs (Skobrák et al., 2011).

Table 3. Fatty acid composition of pork (*Longissimus dorci* muscle) obtained from semi-intensive and free-range rearing systems.

Fatty acid	Carbon No.	Samples		SEM	p-value
		SI	FR		
Myristic	C14:0	5.53	2.21	1.14	0.32
Pentadecanoic	C15:0	0.12	0.09	0.03	0.31
Palmitic	C16:0	26.06	24.05	1.26	0.54
Palmitoleic	C16:1	26.06	24.05	1.26	0.67
Stearic	C18:0	2.90	3.38	0.66	0.81
Oleic	C18:1(n-9)	10.51	9.49	1.27	0.07
Vaccenic	C18:1(n-7)	35.87b	41.61a	1.58	0.04
Linoleic	C18:2(n-6)	2.90	3.00	0.52	0.11
Linolenic	C18:3(n-3)	0.55	0.52	0.12	0.71
Octadecatetranoic	C18:4(n-4)	0.42	0.25	0.20	0.48
11-eicosenoic	C20:1(n-9)	0.57	0.57	0.01	0.31
Arachidonic	C20:4(n-6)	Not determined	Not determined	-	-
Eicosapentaenoic	C20:5(n-3)	1.29	1.63	0.57	0.06
Erucic	C22:1(n-9)	Not determined	Not determined	-	-
Docosatetraenoic	C22:4(n-6)	Not determined	Not determined	-	-
Docosapentaenoic	C20:5(n-6)	0.48	0.22	0.11	0.48
Docosahexaenoic	C22:6(n-3)	0.52	0.37	0.15	0.11

SI, semi-intensive; FR, free-range; SEM, standard error of mean.

a, b: Means in a row with different letters are significantly different ($p < 0.05$).

According to the results of the present study, the monounsaturated fatty acids (MUFA) level has been higher in pork, which was obtained from the free-range system ($p < 0.05$) (Table 4). However, pork from the semi-intensive system reported a markedly higher content of saturated fatty acids and an n-6 : n-3 ratio ($p > 0.05$). Similarly, some scholars have studied the rearing conditions of pigs, and results showed higher levels of omega-3 fatty acid and vitamin E in back fat and intra-muscle fat of animals raised in extensive systems (Lebret and Mourot, 1998). In contradictory, Bee et al. (2004) has reported that the percentage of monounsaturated fatty acid decreased, and the proportion of PUFA was increased in the *Longissimus* muscle of outdoor pigs compared to the *Longissimus* muscle of indoor reared pigs. These changes were attributed to lower proportions of oleic acid and higher proportions of linoleic (18:2(n-6)), eicosadienoic (20:2(n-6)), linolenic (18:3(n-3)) and docosapentaenoic (22:5(n-3)) acids in the *Longissimus* muscle from outdoor reared pigs than indoor reared pigs. Fatty acids like oleic, linoleic, arachidonic, eicosapentaenoic, docosahexaenoic are the fatty acids that give flavour to the product.

The comparison between sensory evaluation scores of pork obtained from cross-bred pigs reared under semi-intensive and free-range systems is presented in Table 5. Pork obtained from both the free-range system and the semi-intensive system showed no difference between any of sensory attributes, i.e., appearance, color, taste, juiciness, tenderness and overall acceptability ($p > 0.05$) (see Table 5 and Fig. 1). However, pork obtained from the free-range system had a numerically higher score than pork obtained from the semi-intensive system for appearance, taste, juiciness and tenderness (Fig. 1). This may be due to the higher water holding capacity observed in *longissimus dorsi* muscle obtained from free-range reared pigs. In contrast, a previous study done by Tomović et al. (2014) found that M. *Longissimus dorsi* (obtained from free-range reared swallow-belly Mangulica pigs) had the lightest color (sensory score, L* value, a* value) and sensory marbling score ($p < 0.05$) when compared to M. *psoas* major, M. *semimembranosus*, and M. *triceps brachii* muscles where similar have been produced by the present study also. Further, the visual scores for color, discoloration, and browning were similar between the two groups of rearing, similar results were found in this study in agreement with previous literature (Gentry et al., 2002). The results of the present study are also following the findings of Edwards (2005) which explained as; when aware of the origin, panellists rated free-range pork as juicier, less bland, less tough, tender, less dry, and more pleasant.

Table 4. Fatty acid profile of pork (*Longissimus dorci* muscle) obtained from semi-intensive and free-range rearing systems.

Fatty acid	Samples		SEM	p-value
	SI	FR		
Saturated fatty acids (SFA)	42.22	35.83	3.50	0.32
Monounsaturated fatty acid (MUFA)	39.06b	44.9a	1.52	0.02
Polyunsaturated fatty acid (PUFA)	15.3	15.48	2.91	0.08
Saturated and unsaturated fatty acid (USFA)	54.36	60.37	3.92	0.06
SFA : USFA	1.38	1.69	0.22	0.19
n6 : n3	9.07	6.27	3.81	0.38

SI, semi-intensive; FR, free-range; SEM, standard error of mean.

a, b: Means in a row with different letters are significantly different ($p < 0.05$).

Table 5. Estimated median values for sensory attributes of pork (*Longissimus dorci* muscle) obtained from semi-intensive and free-range rearing systems.

Attribute	Fresh meat samples		SEM	p-value
	SI	FR		
Appearance	3.80	3.97	0.18	0.23
Color	3.63	3.67	0.20	0.33
Taste	3.70	3.83	0.16	0.06
Juiciness	3.30	3.73	0.20	0.40
Tenderness	3.60	3.73	0.18	0.21
Overall acceptability	3.83	3.83	0.20	0.28

SI, semi-intensive; FR, free-range; SEM, standard error of mean.

a, b: Means in a row with different letters are significantly different ($p < 0.05$).

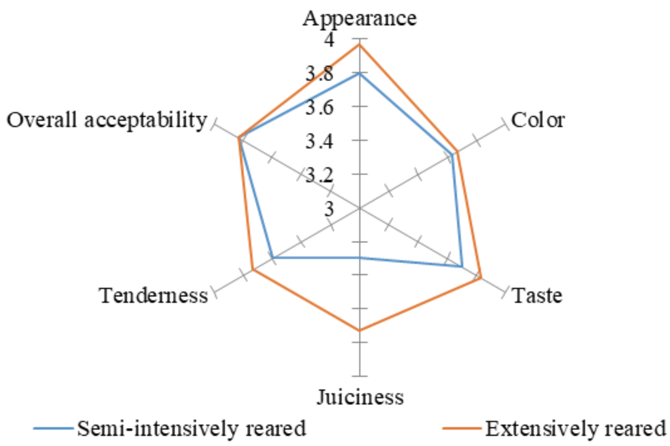

Fig. 1. Web diagram for sensory evaluation of *Longissimus dorci* muscle of extensively reared (free-range system of pig rearing) and semi-intensively reared pigs.

Conclusion

It can be concluded that the rearing system has no significant influence on meat quality parameters, composition and sensory attributes of pork. The forced exercise can be led to the production of lean meat and change some of meat quality parameters like texture, flavor and color along with the feeds and feeding pattern which could affect the compositional changes in meat.

Conflict of Interests

No potential conflict of interest relevant to this article was reported.

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