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A comparison of the physiochemical features of three tertiary hybrid pigs with and without spent coffee ground supplementation

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Abstract
The objective of this experiment was to evaluate the physiochemical characteristics of three tertiary hybrids (crossbreeds) of pigs, with and without coffee supplementation. A total of fifty pigs of different mixed breeds Landrace × Yorkshire × Duroc (LYD), Yorkshire × Berkshire (YB), and Yorkshire × Woori (YW); 113.45 kg ± 3.33 kg at age 190 days old were employed to measure the effect of spent coffee grounds (SCG) from Gangneung-Si area of Korea on the meat quality of pigs in the pigsty at the Kangwon National University Teaching and Research Farm using the 2 × 2 factorial arrangements. Our result shows that the fat percentage was higher ($p < 0.05$) in YB and YW. pH was higher ($p < 0.05$) in the YB breed. Meat colour a* was higher ($p < 0.05$) in the YB and YW breeds. Meat colour b* was higher ($p < 0.05$) in YW. Water holding capacity was higher ($p < 0.05$) in the YB and YW breeds. Drip loss 6 was lower ($p < 0.05$) in YB and YW. Cooking loss was higher ($p < 0.05$) in LYD and YW breeds. The fatty acid components such as linolenic (C18:2), myristic (C14:0), and palmitoleic (C16:1) were higher ($p < 0.05$) in the YB. Palmitic (C16:0), stearic (C18:0), and arachidic (C20:0) was higher ($p < 0.05$) in YW. Lignoceric (C24:0) was higher ($p < 0.05$) in LYD and YW. Unsaturated fatty acid (UFA) was higher ($p < 0.05$) in YB and YW, while polyunsaturated fatty acid (PUFA) was higher ($p < 0.05$) in YB. Monosaturated fatty acid (MUFA) / PUFA was higher ($p < 0.05$) in LYD. Saturated fatty acid (SFA) was higher ($p < 0.05$) in YW. UFA and MUFA were higher ($p < 0.05$) in the YB. MUFA / PUFA were higher ($p = 0.05$) in YB. We concluded from our results that YW and YB had close meat qualities in terms of firmness and flavour compared to LYD as the physiochemical characteristics of meat were improved. SCG supplemented at 0.5% had no detrimental effect on the parameters measured.

Keywords: Korean Woori pig, Coffee waste, Water holding capacity, Meat quality, Fat firmness, Cooking loss

INTRODUCTION

Coffee is the most common global beverage after water, with millions of tons being produced worldwide [1]. However, coffee residues and by-products are major environmental contaminants, especially in regions where coffee is produced in large amounts. From the 20th century till date, many

of this study can be available from the corresponding author.

Authors' contributions
Conceptualization: Mun JY.
Data curation: Ha SH.
Formal analysis: Ha SH.
Methodology: Tajudeen H.
Software: Mun JY.
Validation: Kim JS.
Investigation: Tajudeen H.
Writing - original draft: Tajudeen H.
Writing - review & editing: Tajudeen H, Ha SH, Mun JY, Kim JS.

Ethics approval and consent to participate
The Institutional Animal Care and Use Committee of Kangwon National University approved the animal care and experimental techniques utilized in this study (Ethical code: KW- 220413-1).

efforts have been made to develop viable ways of converting coffee waste into other valuable products, such as feeds, biogas, pectic enzymes, and proteins [2]. Extensive research has also been conducted to investigate the possible benefits of using coffee residue.

One of the primary by-products of coffee is spent coffee grounds (SCG), which are derived from brewing coffee seeds. Manufacturing 1 kilogram (kg) of green coffee generates approximately 0.65 kg of SCG, whereas producing 1 kg of instant brewed coffee generates approximately 2 kg of wet SCG [3]. Using coffee by-products, especially SCG, as an animal feed source was initially unpopular because of their poor starch quality, which is comparable to that of low-quality hay. However, a growing body of research has examined its application as a dietary additive for swine, poultry, and other livestock because of its constant availability, high volume, and low price [3]. For instance, coffee by-products may be used as livestock feed supplements to reduce the cost of production. In particular, SCG has been found to be a viable source of protein and lipids, and it contains minute quantities of polyunsaturated fatty acids (PUFA) [4]. However, SCG is an unpalatable by-product of instant coffee production and contains diuretics, tannins, and caffeine. Therefore, SCG supplements should not exceed 2.5% of any feed [5]. Using by-products from coffee in various farm animal diets may help reduce the cost of production and waste management; however, the effect of SCG on the meat quality of different pig breeds has not been extensively studied. The consumption of pork is substantially increasing in Korea. However, the Duroc (D) and other popular breeds that are commonly used as breeding stock are sourced from the United States of America and Canada. However, in most cases, this results in high foreign exchange costs and other expenses for breeding companies [6]. To reduce these costs, it is essential to develop other breeds, including local Korean pig breeds. It is also important to note that breed plays a significant role in meat quality [7], and creating high-quality pork is crucial for boosting revenues in the pig industry [8]. Landrace (L), Yorkshire (Y), and D three-way hybrids (crossbreeds) (LYD) are frequently used in Korea [9]. Due to their large litter size, rapid growth, and high meat production, L pigs are frequently employed as fattening pigs, whereas D pigs have an excellent growth rate and high fat content. However, crossbreeds primarily developed for meat production, such as LYD, may produce pork of poor quality, with unstable fat firmness and poor water-holding capacity (WHC) [10]. Traditional Korean pig breeds have better meat qualities, such as firm fat tissue, good texture, and a unique flavour that can please Korean customers, but they have low economic value because of their low feed efficiency, growth rate, and output rate [11].

Therefore, the purpose of the current study was to evaluate the digestibility, antioxidant activity, meat colour, WHC, pH, cooking loss (CL), cooking moisture, drip loss (DL), and various fatty acid characteristics of the belly and loin of different crossbreeds of pigs when fed diets supplemented with and without SCG.

MATERIALS AND METHODS

The Institutional Animal Care and Use Committee of Kangwon National University approved the animal care and experimental techniques utilized in this study (Ethical code: KW- 220413-1).

Test animals, feed, and experimental design

A total of fifty pigs of different mixed breeds LYD, Yorkshire × Berkshire (YB), and Yorkshire × Woori (YW); 113.45 kg ±3.33 kg at age 190 days old were employed to measure the effect of coffee extract from Gangneung-Si Korea on the meat quality of pigs in the pigsty at the Kangwon National University Teaching and Research Farm, and pigs with good conformity were selected for this experiment. The corn-soybean feed utilized was made available *ad libitum* and designed to meet

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or surpass the National Research Council's nutrient standards [12] and was supplied in a powdered form (Table 1). 2 × 2 factorial arrangements were used with a section containing the breeds without coffee LYD, YB, and YW, and breeds YB and YW with coffee, with the experiment containing ten pigs per treatment and one pig per replicate. The SCG with nutrient composition as shown in Table 2 was oven dried at 105℃ for 24h to reduce the moisture content. It was then stored in airtight bags at room temperature and eventually premixed at 0.5% per 20 kg of the corn-soybean feed.

All test animals were killed and used fresh directly from the processing unit. The left side of the carcasses' loins and bellies were used to gauge several parameters of meat quality. The loins and bellies were used for all samples, and the muscles' extra fat and bone were removed.

Proximate analysis of pork

The proximate analysis was examined following the AOAC 2012 standard [13]. Weight loss after 12 hours at 105℃ in a drying oven was used to determine the moisture content (AOAC

Table 1. Ingredient and chemical composition of basal diets (as-fed)

Item	CON
Ingredient (%)	100.0
Corn	74.43
Soybean meal (44%)	20.29
Beef tallow	0.23
Molasses (sugar beet)	3.00
L-Lysine (78.8%)	0.05
Limestone	0.70
DCP	0.60
Salt	0.30
Choline	0.05
Mineral[1)]	0.15
Vitamin[2)]	0.15
Phytase	0.05
ME	3,300
CP	14.00
Ca	0.54
P(Total)	0.47
P(STTD)	0.24
Lys	0.73
Met	0.23
MetCys	0.47
Phe	0.69
Thr	0.48
Trp	0.15
Val	0.66

[1)]Supplied per kilogram of diet: 8,000 IU vitamin A, 1,500 IU vitamin D3, 16 mg vitamin E, 1.0 mg vitamin B1, 8.0 mg vitamin B2, 1.6 mg vitamin B6, 0.03 mg vitamin B12, 1.0 mg vitamin K3, 16 mg pantothenic acid, 30 mg niacin, 0.06 mg biotin, 0.26 mg folic acid and 4.8 mg ethoxyquin.

[2)]Supplied per kilogram of diet: 150 mg Fe as ferrous sulfate, 96 mg Cu as copper sulfate, 72 mg Zn as zinc sulfate, 46.5 mg Mn as manganese sulfate, 0.9 mg I as calcium iodate, 0.9 mg Co as cobalt sulfate and 0.3 mg Se as sodium selenite.

DCP, dicalcium phosphate; STTD, standardized total tract digestibility; Lys, lysine; Met, methionine; Cys, cysteine; Phe, phenylalanine; Thr, threonine; Trp, tryptophane; Val, valine.

Table 2. Nutrient composition of spent coffee grounds in %

Item	
Crude protein	7.65
Ether extract	0.28
Crude fibre	26.68
Ash	1.99
Caffeine	1.76

method 950.46B) (SW-90D, Sang Woo Scientific, Bucheon, Korea). The Soxhlet model was used to evaluate the fat content (AOAC method 960.69) by employing a solvent evaporator system (Soxtec® Avanti 2050 Auto System, Foss Tecator AB, Höganäs, Sweden), and the Kjeldahl nitrogen analyzer (Kjeltec® 2300 Analyzer Unit, Foss Tecator AB) was used to determine the protein content (AOAC method 981.10).

Antioxidant activity

The samples were pre-treated and examined following the Cayman kit handbook (Enzyme activity assay, Cayman Chemical, Ann Arbor, MI, USA). Belly and loin samples were analyzed for the concentrations of malondialdehyde (MDA) (Cat. #10006438, Cayman Chemical). According to the instructions in the Cayman kit's manufacturer's manual, a microplate reader (Power Wave XS, BIoTeK, Winooski, VT, USA) was employed to examine the absorption detection [14].

Meat quality

Meat colour

In order to measure the meat's colour, the belly and loin muscles were separated from the skin, tendon, and fat. A Chroma Meter CR-400 device (Minolta Co, Osaka, Japan) was used to measure the colour in line with the CIE L*, a*, and b* standards which is the International Commission on Illumination Standards.

Water holding capacity (WHC in %)

The evaluation of WHC was done by depositing 0.5 g of the specimen on a round plastic plate in a tube (Millipore Ultra free-MC, Millipore, Bedford, MA). The specimens were then subjected to a temperature of 80℃ in a water bath for 20 minutes and then cooled afterward to 23℃. The specimen was then centrifuged (2,000×g) for 10 minutes at 4℃ to determine WHC using the formula, WHC = (moisture content – water loss)/moisture content × 100.

pH

A 5 g sample of pork belly and loin was homogenised in 45 mL of distilled water using a DIAX 900, Heidolph, Kelheim, Germany homogenizer for 15 seconds. The pH meter (Orion 230A, Thermo Fisher Scientific, Waltham, MA, USA) was then used to measure the pH level, and the homogenized samples were filtered using Watman no. 2 (Hillsboro, OH, USA) after the pH procedure.

Cooking loss (%)

3 g of pork belly and loin were heated to 85℃ for 20 minutes in a water bath using an airtight polyethylene container before being allowed to cool to 25℃. Using the formula (sample weight before cooking/sample weight after cooking)/sample weight before cooking × 100, we calculated

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the CL afterward.

Drip loss

At 24 hours postmortem, belly and loin samples were cut and weighed immediately, then recorded as the initial DL weight. The samples were kept in netting and hung in a pressurized bag to prevent subsequent contact between the samples and the bag. The loin and belly samples were gently removed from the bag and allowed to dry after 6-, 12-, 24-, and 48-hours postmortem period respectively. DL was calculated as the percentage of the final sample weight following dripping over the initial sample weight for the different hours as stated above.

Fatty acid analysis (%)

Following the methodology of Folch et al. [15], total fat was examined by adding 5 g of lipids from the samples to a solution of chloroform/methanol in (2:1) with butylated hydroxytoluene. A potassium hydroxide methanol solution was used to create fatty acid methyl esters (FAMEs), which were then extracted using water and hexane. Anhydrous Na_2SO4 was used to dehydrate the top hexane layer that contained FAMEs. The extracted hexane was then dried and transferred into a vial for testing. Gas chromatography (Agilent 7890N, Agilent Technologies, Seoul, Korea) with a flame ionisation detector and capillary column (30 m, 0.32 mm id, 0.25 m, Omega wax 320, Supelco, St. Louis, MO, USA) was used to separate and measure FAMEs via an inlet with a 100:1 split ratio. The carrier gas was high-purity nitrogen, and the flow rate was 1 mL/min. After holding the oven temperature at 180℃ for five minutes, it was raised to 200℃ at a rate of 2.5℃/min and maintained for 25 minutes. Temperatures for the injector and detector were 25℃ and 26℃, respectively.

Statistical method

The data were accumulated using a 2 × 2 factorial arrangement in a completely randomised design which was analysed using the statistical analysis system (SAS) and general linear model (GLM) (SAS Institute, Cary, NC, USA). The main effects for differentiating treatments were LYD, YB, and YW, with the parameters, treatments, and individual pigs serving as the repeated experimental unit. The Tukey test was employed for post hoc testing, and the disparity was considered statistically significant when the p-value was less than 0.05 ($p < 0.05$) in the experimental units

RESULTS

Proximate analysis and MDA

Table 3 shows a comparison of the belly and loin of different breeds of pigs fed diets with and without SCG supplementation. In the belly, the fat percentage was higher ($p < 0.05$) in the YB breed than in the LYD and YW breeds. In the loin, the fat percentage was higher ($p = 0.050$) in the YW breed than in the LYD breed. There were no significant differences in protein, moisture, and MDA across the breeds. There were also no significant effects on the measured parameters for the YB and YW breeds when their diets were supplemented with SCG.

pH and meat colour

The pH and meat colour in the belly and loin are shown in Table 4 of our study. In the belly, the pH was higher ($p < 0.05$) in the YB than in the YW breed. Meat colour a* was higher ($p < 0.05$) in the YB and YW breeds compared to that in the LYD breed. There were no significant differences in meat colour (L*and b *) in the belly. In the loin, the pH was higher ($p < 0.05$) in the YB breed than in the LYD breed. Meat colour b* was higher in the YW group ($p < 0.05$) than in the YB

Table 3. Comparing the proximate analysis, and antioxidant activity of different breeds of pigs with and without coffee supplementation

	Coffee –[1)]			Coffee +		SEM	*p*-value	
	LYD	YB	YW	YB	YW		Breeds	YB vs YW
	0	1	3	2	4		0 vs 1 vs 3	1 + 2 vs 3 + 4
Belly								
Protein	14.56	14.11	14.30	14.35	14.70	0.711	0.433	0.821
Fat (%)	32.23[b]	35.07[a]	33.02[b]	35.27	32.90	0.445	< 0.001	0.735
Moisture (%)	48.74	45.03	47.61	48.53	47.46	1.085	0.459	0.084
MDA	4.06	3.22	3.98	3.57	3.70	0.229	0.064	0.182
Loin								
Protein	22.12	21.16	21.66	21.38	21.71	0.252	0.147	0.944
Fat (%)	3.46[b]	3.70[ab]	3.96[a]	3.72	3.99	0.114	0.050	0.950
Moisture (%)	70.47	72.40	71.32	71.15	71.94	0.579	0.805	0.118
MDA	0.87	0.64	0.79	0.68	0.74	0.070	0.131	0.285

[1)]–, without SCG; +, with 0.5% SCG.

[a,b]Mean values within a row with different superscript letters were significantly different ($p < 0.05$).

LYD, Landrace × Yorkshire × Duroc; YB, Yorkshire × Berkshire; YW, Yorkshire × Woori; MDA, malondialdehyde; SCG, spent coffee grounds.

Table 4. Comparing the pH and meat color of different breeds of pig with and without coffee supplementation

	Coffee –[1)]			Coffee +		SEM	*p*-value	
	LYD	YB	YW	YB	YW		Breeds	YB vs YW
	0	1	3	2	4		0 vs 1 vs 3	1 + 2 vs 3 + 4
Belly								
pH	5.97[ab]	6.10[a]	5.76[b]	6.06	5.67	0.082	< 0.001	0.754
Meat color L*	51.56	48.87	50.14	50.75	51.04	0.930	0.285	0.065
Meat color a*	13.74[b]	18.43[a]	17.43[a]	18.28	17.18	0.495	0.044	0.921
Meat color b*	2.70	3.37	3.58	3.19	3.42	0.485	0.681	0.978
Loin								
pH	5.79[b]	6.13[a]	5.89[ab]	6.07	5.89	0.061	0.005	0.634
Meat color L*	51.69	53.12	54.11	53.13	54.03	0.737	0.164	0.944
Meat color a*	16.66	17.37	17.47	17.79	17.84	0.344	0.814	0.950
Meat color b*	3.82[ab]	3.09[b]	4.86[a]	3.47	4.03	0.527	0.049	0.285

[1)]–, without SCG; +, with 0.5% SCG.

[a,b]Mean values within a row with different superscript letters were significantly different ($p < 0.05$).

LYD, Landrace × Yorkshire × Duroc; YB, Yorkshire × Berkshire; YW, Yorkshire × Woori; SCG, spent coffee grounds.

group. There was no significant difference in meat colour, L*, and a*, in the loins. There were also no significant effects on the measured parameters for the YB and YW breeds when their diets were supplemented with SCG.

Meat quality

Table 5 shows the result for meat quality in our study. In the belly, the WHC was higher ($p < 0.05$) in the YB and YW breeds than in the LYD breed. The DL6 was lower ($p < 0.05$) in the YB and YW breeds than in the LYD breed. Among the breeds, there were no significant differences in the CL, DL 12, 24, and 48 in the belly. In the loin, the CL was higher ($p < 0.05$) in the LYD and YW breeds than in the YB breed. There were no significant differences in WHC, DL6, 12, 24, and 48 in the loin. There were also no significant effects on the measured parameters for the YB and YW

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Table 5. Comparing the meat quality of different breeds of pig with and without coffee supplementation (%)

	Coffee –[1)]			Coffee +		SEM	*p*-value	
	LYD	YB	YW	YB	YW		Breeds	YB vs YW
	0	1	3	2	4		0 vs 1 vs 3	1 + 2 vs 3 + 4
Belly								
WHC	67.48[b]	72.36[a]	70.53[a]	73.20	71.37	0.735	0.008	0.999
Cooking loss	25.35	24.86	25.93	25.67	26.13	1.200	0.426	0.753
Drip loss 6	1.91[a]	1.14[b]	1.48[b]	1.07	1.31	0.103	0.003	0.559
Drip loss 12	2.05	1.74	2.28	1.94	2.08	0.226	0.154	0.389
Drip loss 24	0.96	0.74	0.94	0.90	0.97	0.111	0.273	0.596
Drip loss 48	0.67	0.54	0.45	0.58	0.54	0.085	0.478	0.775
Loin								
WHC	81.26	83.03	81.85	83.13	81.99	0.700	0.074	0.980
Cooking loss	31.13[a]	27.84[b]	30.15[a]	27.99	30.45	0.799	0.005	0.926
Drip loss 6	3.23	1.97	2.04	1.99	2.01	0.244	0.835	0.912
Drip loss 12	1.29	1.20	1.35	1.05	1.04	0.119	0.495	0.397
Drip loss 24	1.31	1.02	1.09	1.14	1.17	0.094	0.614	0.814
Drip loss 48	0.54	0.65	0.57	0.56	0.54	0.110	0.645	0.770

[1)]–, without SCG; +, with 0.5% SCG.

[a,b]Mean values within a row with different superscript letters were significantly different ($p < 0.05$).

LYD, Landrace × Yorkshire × Duroc; YB, Yorkshire × Berkshire; YW, Yorkshire × Woori; WHC, water holding capacity; SCG, spent coffee grounds.

breeds when their diets were supplemented with SCG.

Fatty acid composition

The fatty acid composition was shown in Tables 6 and 7 of our experiment. In the belly, the linolenic (C18:2) content was higher ($p < 0.05$) in the YB than in the LYD breed. However, there were no significant differences in belly lauric (C12:0), myristic (C14:0), palmitic (C16:0), palmitoleic (C16:1), stearic (C18:0), oleic (C18:1), linolenic (C18:3), arachidic (C20:0), or lignoceric (C24:0) content across breeds. In the loin, the C14:0 content was higher ($p < 0.05$) in the YB breed than in the YW or LYD breeds. The C16:0 content was higher ($p < 0.05$) in the YW breed than in the LYD or YB breeds. The C16:1 content was higher ($p < 0.05$) in the YB breed than in the YW and LYD breeds. The C18:0 content was significantly higher ($p < 0.05$) in the YW breed than in the YB breed. The C20:0 content was higher ($p < 0.05$) in the YW breed than in the LYD or YB breeds. The C24:0 levels were higher ($p < 0.05$) in the LYD and YW breeds than in the YB breed. The levels of unsaturated fatty acids (UFA) were higher ($p < 0.05$) in the YB and YW breeds than in the LYD breed (Table 7). The levels of PUFA were higher ($p < 0.05$) in the YB breed than in the LYD breed. The monosaturated fatty acid (MUFA) / PUFA ratio was higher ($p < 0.05$) in the LYD breed than in the YW and YB breeds. There were no significant differences in the levels of saturated fatty acids (SFA) and MUFAs in the belly across the breeds. In the loin, the levels of SFA were higher ($p < 0.05$) in the YW breed than in the LYD or YB breeds. The levels of UFA and MUFA were higher in the YB breed than in the LYD and YW breeds. In addition, the levels of MUFA and PUFA were higher ($p < 0.05$) in the YB breed than in the YW breed. Finally, there was no significant difference in the PUFA content of the loins when all breeds were compared. There were also no significant effects on the measured parameters for the YB and YW breeds when their diets were supplemented with SCG.

Table 6. Comparing various fatty acid composition of different breeds of pigs with and without coffee supplementation (%)

	Coffee –[1)]			Coffee +		SEM	*p*-value	
	LYD	YB	YW	YB	YW		Breeds	YB vs YW
	0	1	3	2	4		0 vs 1 vs 3	1 + 2 vs 3 + 4
Belly								
Lauric (C12:0)	0.155	0.197	0.167	0.177	0.182	0.014	0.350	0.195
Myristic (C14:0)	0.400	0.528	0.402	0.535	0.487	0.049	0.093	0.438
Palmitic (C16:0)	29.253	31.565	32.353	31.087	31.613	0.528	0.162	0.776
Palmitoleic (C16:1)	2.720	3.180	3.062	3.097	3.052	0.066	0.210	0.567
Stearic (C18:0)	11.363	12.827	13.173	12.962	13.007	0.375	0.572	0.663
Oleic (C18:1)	37.810	40.565	39.580	40.877	39.875	0.748	0.200	0.991
Linoleic (C18:2)	10.305[b]	13.468[a]	11.750[ab]	13.528	12.123	0.456	0.002	0.731
Linolenic (C18:3)	0.728	0.645	0.663	0.650	0.665	0.038	0.623	0.961
Arachidic (C20:0)	0.167	0.172	0.165	0.172	0.168	0.007	0.514	0.827
Lignoceric (C24:0)	1.140	1.105	1.088	1.127	1.118	0.019	0.522	0.830
Loin								
Lauric (C12:0)	0.103	0.145	0.152	0.148	0.158	0.006	0.193	0.791
Myristic (C14:0)	1.507[b]	2.048[a]	1.498[b]	2.002	1.523	0.078	< 0.001	0.592
Palmitic (C16:0)	23.148[b]	23.138[b]	24.130[a]	23.187	24.053	0.386	< 0.001	0.801
Palmitoleic (C16:1)	3.028[b]	6.152[a]	3.037[b]	6.118	3.140	0.096	< 0.001	0.507
Stearic (C18:0)	12.182[ab]	11.732[b]	12.712[a]	11.870	12.485	0.308	0.021	0.572
Oleic (C18:1)	42.055	42.813	41.850	43.107	42.508	0.457	0.089	0.680
Linoleic (C18:2)	10.982	11.752	11.243	11.558	11.277	0.208	0.060	0.573
Linolenic (C18:3)	0.572	0.548	0.527	0.535	0.520	0.029	0.548	0.913
Arachidic (C20:0)	0.210[b]	0.208[b]	0.288[a]	0.213	0.297	0.017	< 0.001	0.912
Lignoceric (C24:0)	1.447[a]	1.268[b]	1.543[a]	1.287	1.532	0.075	0.003	0.846

[1)]–, without SCG; +, with 0.5% SCG.

[a,b]Mean values within a row with different superscript letters were significantly different ($p < 0.05$).

LYD, Landrace × Yorkshire × Duroc; YB, Yorkshire × Berkshire; YW, Yorkshire × Woori; SCG, spent coffee grounds.

DISCUSSION

In our study, the fat content responsible for meat firmness and flavour was higher in the YB and YW breeds compared with LYD. Certain fats and fatty acids contribute immensely to several aspects of meat quality. They are essential to the nutritional content and juiciness of meat, although they have been reported to be harmful by several studies based solely on their nature and the category of fat to which they belong [16,17]. The firmness and taste of pork are primarily determined by its moisture content and adipose tissue composition, which is important because different fats have different melting points. Our results are similar to those of Kim and Kim [18] who found that the fats responsible for firmness and flavour were higher in the Korean native Woori breed than in the LYD breed. The fat content in the YW and YB breeds is thought to be due to the comparatively high intramuscular fat content of the native Korean pig and the YB breed [19,20].

Pork is naturally acidic, and its pH affects the interaction of proteins in fresh and processed pork [21], Thus, pH is a fundamental component of meat quality. Factors such as breed, nutrition, and management affect the final pH of meat [22,23]. Several protein characteristics, such as solubility, function, colour, and WHC, are directly affected by pH [24], and extremely low pH values usually

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Table 7. Comparing various saturated, unsaturated, monounsaturated, and polyunsaturated fatty acids characteristics of different breeds of pigs with and without coffee supplementation (%)

	Coffee –[1)]			Coffee +		SEM	*p*-value	
	LYD	YB	YW	YB	YW		Breeds	YB vs YW
	0	1	3	2	4		0 vs 1 vs 3	1+2 vs 3+4
Belly								
SFA	42.475	46.388	47.347	46.052	46.570	0.722	0.273	0.741
UFA	51.558[b]	57.858[a]	55.053[a]	58.152	55.715	0.845	0.005	0.827
MUFA	40.528	43.747	42.640	43.973	42.927	0.737	0.155	0.968
PUFA	11.032[b]	14.112[a]	12.412[ab]	14.178	12.788	0.487	0.002	0.726
MUFA / PUFA	3.742[a]	3.107[c]	3.470[b]	3.123	3.367	0.159	0.028	0.644
Loin								
SFA	38.597[b]	38.535[b]	40.322[a]	38.697	40.038	0.512	< 0.001	0.496
UFA	56.635[b]	61.260[a]	56.653[b]	61.313	57.438	0.504	< 0.001	0.450
MUFA	45.082[b]	48.963[a]	44.885[b]	49.222	45.643	0.479	< 0.001	0.605
PUFA	11.553	12.298	11.770	12.093	11.797	0.211	0.052	0.568
MUFA / PUFA	3.910[ab]	3.990[a]	3.820[b]	4.078	3.873	0.085	0.037	0.837

[1)]–, without coffee; +, with 0.5% SCG.

[a,b]Mean values within a row with different superscript letters were significantly different ($p < 0.05$).

3LYD, Landrace × Yorkshire × Duroc; YB, Yorkshire × Berkshire; YW, Yorkshire × Woori; SFA, saturated fatty acid; UFA, unsaturated fatty acid; MUFA, monosaturated fatty acids; PUFA, polyunsaturated fatty acids; SCG, spent coffee grounds.

have a negative impact on these qualities [25]. In our study, the YB breed had the highest pH values in the belly and loin compared to the YW breed (in the belly) and the LYD breed (in the loin), which could explain the increase in a* in the YB breed. Lonergan et al. [21] reported that the pH in the muscle and other denatured meat drops rapidly and encourages the production of sarcoplasmic protein, a water-soluble protein in the muscle that can impact meat colour and WHC. However, this process may be slowed if the meat is chilled. Preventing the denaturation of myoglobin, which gives meat its colour, is crucial because consumer preference is related to meat colour. It has also been found that a lighter colour results from a reduced final pH and vice versa [24,26]. This may explain the high a* meat colour in the belly of the YB breed and the b* meat colour seen in the YW breeds. As previously mentioned, pH also greatly contributes to the WHC, which determines the meat quality parameters DL and CL. The ability of pork to bind water is due to the activity of several proteins [27].

The two myofibrillar proteins actin and myosin are water-binding proteins that are affected by pH [22]. In our study, we found that the WHC was higher in the bellies of the YB and YW breeds, which had a lower DL6. However, the WHC for the YB breed was 72.36 with a higher belly pH, whereas that for the YW breed was 70.53 with a lower belly pH. The YB breed had a higher belly pH, and its DL6 was as low as 1.14. The YW breed had a higher belly pH, and its DL6 was 1.48. The reduced CL in the YB loin can be attributed to its increased pH, suggesting that a combination of high temperatures and low pH can trigger the denaturation of myosin [21]. Denatured myosin is less functional as a result of minute water-binding protein availability. Although the pH values for the bellies in the YB and YW breeds in our study were almost incomparable, they had similar red meat colours, WHC, and DL. These attributes in the YW breed can be ascribed to the ability of native Korean pigs to produce higher levels of myosin and to the configuration of their firm and red muscle fibres. A higher myoglobin concentration and the presence of enough fat to serve as an energy source for the muscle cells may lead to a higher WHC, red colour, and reduced DL6 [28,29].

Fats and fatty acids are essential components of the pork nutritional profile and substantially contribute to the practical aspects of meat quality and human health after consumption [16]. Consuming high quantities of SFA, such as C14:0, C16:0, and C20:0, can increase the risk of developing type 2 diabetes and cardiovascular disease. Therefore, they should be moderately ingested [30–32]. We found that C14:0 levels were higher in YB loins, whereas C16:0 and C20:0 levels were higher in YW loins. In our study, we found that C18:0, which has the greatest impact on meat firmness, was significantly higher in the loin. This concentration correlates strongly with the melting temperature of lipids and the firmness of carcass fat, which has a melting point of approximately 70℃ [33]. Although C18:0 is regarded as a neutral fatty acid, it increases the level of high-density lipoprotein cholesterol and reduces that of low-density lipoprotein (LDL) cholesterol, which makes it harder for the body to produce more cholesterol [34]. This process leads to the absorption, transport, and removal of cholesterol from the body via the liver. Many UFAs, especially omega-3 fatty acids such as C16:1, are also beneficial to human health and are linked to the flavour and general desirability of meat [35,36]. Consuming UFAs helps prevent disorders such as arteriosclerosis and hypertension, and they are so abundant in meat that they affect its flavour [18]. In our study, C16:1 was higher in the loin of the YB breed, whereas UFA levels were higher in the belly of the YB and YW breeds. In the YB breed, UFA levels were highest in the loin. Essential fatty acids, such as C18:2, also have a positive impact on the heart when they are consumed. Several clinical trials have shown that C18:2 decreases both total and LDL cholesterol levels when it was substituted for saturated fat. The present study found that C18:2 levels were higher in the YB breed. Another group of significant fatty acids that contributes immensely to the taste of pork are MUFAs; however, an increase in MUFAs is accompanied by a proportional decrease in PUFAs [11]. However, PUFAs have been reported to beneficially affect human and animal health [37,38]. Diets rich in PUFAs may reduce inflammation and lower the risk of chronic diseases, such as arthritis, cancer, and heart disease. Our study showed that PUFA levels were higher in YB and YW bellies, whereas MUFA levels were higher in YB loins. Increases in MUFA and PUFA levels are related to changes in fat oxidation, softness, texture, and rancidity. All of these result from the proportional increase in the double bonds of fatty acids, and they can lead to a decline in the melting point and oxidative stability of fats [39]. Our study showed that MUFA and PUFA levels were higher in the belly of the LYD breed, whereas MUFA levels were higher in the loin of the YB breed.

In addition to the qualities of breeds stated above, the supplementation of SCG had no significant effect on all parameters measured. The level of responsiveness by SCG is greatly proportional to the administered dosage, thus, it is paramount to establish the most ideal level of SCG supplementation in diets [40]. We, therefore, propose that the inability of coffee to significantly improve the meat quality of pork in our study may be attributed to the dosage employed. However, our result suggests that the supplementation of SCG up to 0.5% had no detrimental effect on the pig's meat quality.

CONCLUSION

Our result confirmed that YW and YB had similar meat qualities rather than LYD in terms of pork fat firmness and flavour as the physiochemical characteristics of meats including higher unsaturated fat composition, pH, meat redness, WHC, and reduced DL which ultimately improves pork firmness, texture, consumer-preferred colour, and flavour were observed. It was also noticed that the supplementation of SCG at 0.5% had no detrimental effect on the parameters measured.

We, therefore, recommend that employing the Korean Woori pig as a breeding alternative can help ameliorate the dependence on exotic breeds including L, B and D in terms of meat quality

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such as pork fat firmness, colour, and flavour. We also recommend that SCG can be supplemented in finishing pig's diet up to 0.5% with no adverse effects.

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