

Physico-chemical quality attributes and fatty acid profiles of pork from Windsnyer and Large White gilts

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Abstract

The objective of the study was to assess the physico-chemical pork quality attributes and fatty acid profiles of indigenous Windsnyer (WS) and Large White (LW) gilts. Twelve gilts of each breed were fed similar commercial diets from weaning until slaughter at the age of 21 weeks. The *m. longissimus thoracis et lumborum* was sampled. Differences in muscle pH values obtained 24 hours post mortem (pH₂₄) were not significant in pork from the WS or LW gilts. Pork lightness 24 hours post mortem (L₂₄) was significantly lower in WS gilts than in LW gilts. Muscle saturated fatty acids (SFA) were higher in WS gilts than LW gilts. Fat of LW gilts had higher polyunsaturated (PUFA), n-6 fatty acids, n-3 fatty acids and PUFA: SFA ratio than WS gilts. The study showed preferential attributes of pork from LW gilts than from WS gilts. The accrued information could benefit the food industry by assisting researchers and nutritionists to interpret the quality of pork from different pig genotypes for health-conscious consumers. Furthermore, it aids in determining the concern about pork as a cardiovascular risk factor and acts as a planning tool for public-health programmes.

Keywords: Fatty acids, indigenous pigs, pork quality, tenderness

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Introduction

South Africa has about 1.6 million pigs, which are kept for the production of meat to feed the human population (FAOSTAT, 2012). Most of the pigs are reared under commercial farming practices, in which more than 150 metric tonnes of pork are produced annually (Van der Westhuizen, 2011). The most common pig breeds are the Large White, Landrace, Duroc and Pietrien (Halimani *et al.*, 2010). Windsnyer pigs (WS), an indigenous genotype to southern Africa, do not contribute greatly to commercial pork production, because they have slow growth rates, smaller carcasses and tend to deposit fat early when fed high-energy diets (Bester, 2010; Chimonyo *et al.*, 2010). Most of the fat is subcutaneous, can easily be trimmed (Chimonyo *et al.*, 2005) and is used for cooking by poor farmers in rural areas. Most of these indigenous pigs are reared in rural areas of southern Africa, so they rely on scavenging, eating grasses and insects, and digging out roots. This may result in their producing less fat and could provide an opportunity to supply inorganically produced pork for a niche market.

Several studies have reported pork quality attributes of various pig breeds. Hoffman *et al.* (2004) reported pork quality attributes for LW and Landrace crosses. Likewise, pork quality attributes were reported in Yorkshire, Duroc and Landrace breeds in a study by Li *et al.* (2013). Not many attempts have been made to assess the pork quality objectively of WS pigs in southern Africa. These pigs probably produce acceptable pork compared with their counterparts (Landrace, Large White, Duroc and Pietrien) on commercial farms. The promotion of organically produced indigenous pork on the market might enhance the choices for the increasing health-conscious population. The objective of the study, therefore, was to determine the physico-chemical attributes and fatty acids profiles for genetically unimproved South African indigenous WS gilts and

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improved LW gilts. It was hypothesized that there are no differences in physico-chemical attributes and fatty acid profiles between genetically unimproved South African indigenous WS gilts and improved LW gilts.

Materials and Methods

The study was conducted at Fort Cox College of Forestry and Agriculture in the province of Eastern Cape, South Africa. The experiment was managed according to procedures approved by the University of Fort Hare Ethics Committee. A total of twenty-four 6-week-old gilts were used, 12 from each of the WS and LW breeds. Their average weight at weaning was 7.4 ± 0.59 kg and 9.91 ± 0.59 kg, respectively. The LW gilts were obtained from Fort Cox College of Agriculture and Forestry and the WS gilts were obtained from the surrounding communities. At weaning and once a month afterwards, the pigs were dosed and sprayed against gastro-intestinal parasites and ecto-parasites, respectively. Each pig was an experimental unit and they were randomly allocated to pens. The pigs were identified and housed individually in a 3 x 2 m concrete floored and zinc-roofed pen. The walls of each pen were 1.5 m. All pigs were fed a commercial feed (Monti Feeds Pvt Ltd, East London, South Africa) on an *ad libitum* basis. The piglets were weaned at five weeks, and were allowed to adapt to the feed for seven days. From days 35 to 56 the pigs were fed on pig weaner meal (180 g crude protein (CP)/kg, 13 MJ metabolizable energy per kg DM. Pig grower meal (160 g CP/kg, 13.7 MJ ME/kg DM) was offered from Day 57 until Day105. The fatty acid profiles of the pig weaner meal and pig grower meal are shown in Table 1.

Table 1 Fatty acid profiles (as a percentage of total fatty acids identified) in feed given to Large White and Windsnyer gilts before slaughter

Fatty acids	Pig weaner meal	Pig grower meal
14:0	0.15	0.09
16:0	21.26	16.44
16:1c9	0.38	0.13
17:0	0.71	0.10
18:0	5.09	1.77
18:1c9	34.23	24.37
18:1c7	1.50	0.80
18:2c9,12 (n-6)	32.63	53.30
20:0	0.48	0.24
18:3c9,12, 15 (n-3)	2.10	2.46
22:0	0.31	0.12
20:5c5,8,11,14,17 (n-3)	0.12	0.11
24:1c15	1.05	0.05
SFA	28.00	18.77
MUFA	37.15	25.35
PUFA	34.85	55.87
n-6	32.63	53.30
n-3	2.22	2.57
PUFA: SFA	1.24	2.98
n-6: n-3	14.69	20.71

SFA: total saturated fatty acids, MUFA: total monounsaturated fatty acids, PUFA: total polyunsaturated fatty acids, n-6: total omega-6 fatty acids, n-3: total omega-3 fatty acids, c: *cis*, PUFA: SFA: ratio of polyunsaturated fatty acids and saturated fatty acids, n-6: n-3: ratio of n-6: n-3.

The slaughter of pigs was done at Adelaide Municipal abattoir, which is about 80 km from the study site. Pigs were transported on a cool morning, allowed to rest for an hour on arrival, and given water *ad libitum*. They were stunned using the electric stunning method, their jugular veins severed, fully bled and

scalded in hot water afterwards. The carcasses were chilled at 0 °C for 24 hours. After 24 hours, a four-rib (eighth to eleventh) section of *m. longissimus thoracis et lumborum* was removed from the right side of each carcass and identified, and pH and colour were measured. A portable fibre-optic pH meter probe (Crison pH 25 instruments S.A., Alella, Spain) was used to measure pH. The Minolta colour guide 45/0 BYK-Gardener GmbH machine with a 20 mm diameter measurements area and illuminant D65-day light, 10° standard observer was used to measure the muscle colour (L^* : lightness, a^* : redness, and b^* : yellowness). Areas of connective tissue and intramuscular fat were avoided. The *m. longissimus thoracis et lumborum* sections were vacuum packed and kept frozen at -20 °C for two weeks before laboratory analyses. They were then thawed overnight at room temperature, and thawing loss was estimated. The muscles were cut into small pieces, placed in a water tight plastic bag and cooked for 45 minutes in a water bath at 85 °C until 70 °C internal temperature was reached. Afterwards, the samples were left to cool on a table at room temperature and weighed again. Cooking losses and shear force were determined. The backfat samples from the pig breeds were collected according to the method described by Hugo & Roodt (2015).

Total lipid from feed material was extracted with Soxhlet extraction according to AOAC Official Method 920.39 (2005) procedures for determination of fats. Total lipid from backfat (collected on the last rib position) and muscle sample was quantitatively extracted, according to the method of Folch *et al.* (1957), using chloroform and methanol in a ratio of 2:1. A rotary evaporator was used to dry the fat extracts under vacuum and the extracts were dried overnight in a vacuum oven at 50 °C, using phosphorus pentoxide as moisture adsorbent. Total extractable intramuscular fat was determined gravimetrically from the extracted fat and expressed as % fat (w/w) per 100 g tissue. The fat-free dry matter (FFDM) content was determined by weighing the residue on a pre-weighed filter paper, used for Folch extraction, after drying. By determining the difference in weight, the FFDM could be expressed as % FFDM (w/w) per 100 g tissue. The moisture content of the muscle and backfat was determined by subtraction (100% - % lipid - % FFDM) and expressed as % moisture (w/w) per 100 g tissue. Approximately 10 mg of extracted lipid from feed, backfat and muscle was transferred into a Teflon-lined screw-top test tube. Fatty acid methyl esters (FAME) were prepared for gas chromatography by methylation of the extracted fat, using methanol-BF₃ (Christie *et al.*, 2001). FAME from feed and muscle were quantified using a Varian GX 3400 flame ionization GC, with a fused silica capillary column, Chrompack CPSIL 88 (100 m length, 0.25 mm ID, 0.2 µm film thickness), split ratio 100:1. Analysis was performed using an initial isothermic period (40 °C for 2 minutes). Then, temperature was increased at a rate of 4 °C/minute to 230 °C. Finally, an isothermic period of 230 °C for 10 minutes followed. FAME *n*-hexane (1 µL) was injected into the column using a Varian 8200 CX Autosampler. The injection port and detector were both maintained at 250 °C. Hydrogen, at 45 psi, functioned as the carrier gas, while nitrogen was employed as the makeup gas. Varian Star Chromatography software recorded the chromatograms. FAME samples were identified by comparing the retention times of FAME peaks from samples with those of standards obtained from Supelco (Supelco 37 Component Fame Mix 47885-U, Sigma-Aldrich Aston Manor, Pretoria, South Africa). Fatty acids were expressed as the proportion of each individual fatty acid to the total of all fatty acids present in the sample. The omega-3 (n-3), omega-6 (n-6), total saturated fatty acids (SFA), and total monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), PUFA: SFA ratio and n-6 : n-3 ratios were computed.

The effects of pig breed on tenderness, cooking loss, thawing loss, muscle and fat moisture, fat-free dry matter, fat and fatty acid profiles were analysed using general linear model (GLM) procedures of SAS (2008). The effects of pig breed on pH and pork colour were also analysed using GLM of SAS (2008). Significant means were compared using the PDIFF option in SAS (2008).

Results and Discussion

The physico-chemical attributes of pork from WS and LW gilts are shown in Table 2. Pork from LW gilts had higher ($P < 0.05$) thawing loss and cooking loss than WS gilts. Pork from LW gilts had higher L^*_{24} ($P < 0.001$) than pork from WS gilts. Pig breed had no effect on WBSF, pH_{24} , a^*_{24} and b^*_{24} . There was no interaction between pig breed and time on pH and colour. The observed Warner Braztler shear force values for the *m. longissimus thoracis et lumborum* were higher than those reported by Dilger *et al.* (2010). Variations in WBSF might be due to pre- and post-slaughter procedures, and instrumental differences, as reported by Van Oeckel *et al.* (1999). The findings that there were differences in cooking loss between pork from LW and WS gilts agree with those of Renaudeau *et al.* (2005), who reported lower cooking loss (30.2%) in indigenous Creole pigs than the LW breed (33.1%). As observed in the study, differences in cooking losses between LW and WS gilts show the LW to be more susceptible to porcine stress syndrome and to have an increased likelihood of developing pale soft exudative (PSE) meat.

Table 2 Least square mean (\pm standard error) values for Warner Braztler shear force, cooking loss %, thawing loss %, pH and colour of Large White and Windsnyer gilts

Pork quality attributes	Breed		Significance
	Windsnyer (n =12)	Large White (n =12)	
WBSF	24.04 \pm 1.210	22.06 \pm 1.210	NS
Cooking loss %	25.77 \pm 0.480	26.93 \pm 0.480	*
Thawing loss %	6.03 \pm 0.440	7.37 \pm 0.440	*
<i>pH values</i>			
pH ₂₄	5.56 \pm 0.070	5.57 \pm 0.070	NS
Colour measurements			
L ₂₄ *	49.74 \pm 1.240	57.19 \pm 1.240	***
a ₂₄ *	7.22 \pm 0.721	6.47 \pm 0.721	NS
b ₂₄ *	9.20 \pm 0.509	9.80 \pm 0.509	NS

Significance level: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, NS: not significant.

WBSF: Warner Braztler shear force (N), pH₂₄: pH at 24 hours' post slaughter.

L* value represents lightness; a* value represents redness; b* represents yellowness (numeric figures represents number of hours post slaughter).

The cooking loss of LW (26.9%) and WS (25.8%) pigs in the study, however, is far less than that reported for Duroc and Chinese breeds (Meshian, Fenjing, and Minzhu pigs) (Wheeler & Young, 1992). The differences in cooking losses may be attributed to several factors, such as differences in ageing, cooking method, cooking temperatures, duration of cooking temperatures and marbling (Lawrie, 1998; Nour *et al.*, 1994; Yu *et al.*, 2005).

The ultimate pH (pH₂₄) for LW and WS gilts in the current study was similar to that reported for LW sired pigs (Terlouw *et al.*, 2009). Renaudeau & Maurot (2007) reported pH₂₄ values of 5.71 and 5.62 for the indigenous Creole and LW breeds; respectively. The acceptable pH₂₄ range for normal meat is 5.3–5.7. Pork pH₂₄ is responsible for the changes that take place on the muscle. In addition, pH has been reported to affect the colour of meat in some studies. In the current study, pork pH for both breeds was similar. Consequently, the authors cannot explain the variations in colour obtained for the two breeds in the study. These variations maybe breed dependent. According to Gentry *et al.* (2001), pigs are born with a predominance of Type I (darker red) fibres. As they develop, there is a shift to Type IIA and Type IIB fibres. The WS gilts, therefore, still had the predominant Type I fibres at slaughter compared with LW gilts. These observations on colour may suggest a lower incidence of PSE traits in the indigenous WS gilts (Hoffman *et al.*, 2005).

Table 3 shows muscle proximate analysis and fatty acid profiles for WS and LW gilts. Windsnyer gilts had higher ($P < 0.001$) FFDM and SFA ($P < 0.05$) compared with LW gilts. The indigenous WS gilts also had higher ($P < 0.01$) proportions of palmitic (16:0) and arachidic acid (20:0) than LW gilts. The proportions of margaric (17:0) and behenic (22:0) acids, however, were higher ($P < 0.05$) in the muscle of LW gilts than in WS gilts. There were no breed differences in most fatty acids and their ratios, moisture content and marbling. Table 4 shows proximate analysis and fatty acid profiles for backfat in the indigenous WS and exotic LW gilts. Windsnyer gilts had higher ($P < 0.05$) extractable fat, palmitic (16:0), arachidic (20:0) and SFA than LW gilts. Large White gilts, on the other hand, had higher ($P < 0.05$) proportions of FFDM, pentadecanoic (15:0), margaric (17:0), linoleic (18:2c9,12 (n-6)), eicosatrienoic (20:3c11,14,17 (n-3)), arachidonic (20:4c5,8,11,14 (n-6)), PUFA, n-6, n-3 and PUFA/SFA than WS gilts. Fatty acids that were not in the feed but were found in the muscle and backfat of both breeds include arachidonic (20:4c5,8,11,14 (n-6)), γ -linolenic (18:3c6,9,12 (n-6)), heptadecenoic (17:1c10), elaidic (18:1t9) and pentadecanoic. Of these fatty acids, heptadecenoic and γ -linolenic were found only in the muscle and pentadecanoic was found in the backfat.

In both breeds, backfat and muscle fatty acids were deposited in the form that they were presented in the diet, as suggested by Wood *et al.* (2008). Fatty acids that were not in the feed and therefore must have been synthesised in the animal included heptadecenoic and pentadecanoic acids. Differences in fatty acid composition between breeds can be attributed to the PUFA : SFA ratio. This ratio decreases as the level of fat in the meat increases (Enser *et al.*, 1996). The minimum recommended value for PUFA : SFA ratio is 0.4 (Muchenje *et al.*, 2009) and the ideal ratio is 0.7 (Warnants *et al.*, 2001).

Table 3 Muscle proximate analysis and fatty acid profiles (as a percentage of total fatty acids identified) (\pm standard errors) for Large White and Windsnyer gilts

Attributes	Breed		Significance
	Windsnyer (n =12)	Large White (n =12)	
Proximate analysis			
Marbling	2.61 \pm 0.207	2.38 \pm 0.207	NS
FFDM	24.72 \pm 0.323	22.95 \pm 0.323	***
Moisture	72.66 \pm 4.120	68.84 \pm 4.120	NS
Fatty acids and ratios			
14:0	1.32 \pm 0.053	1.31 \pm 0.053	NS
16:0	28.88 \pm 0.190	28.04 \pm 0.190	**
16:1c9	3.36 \pm 0.115	3.39 \pm 0.115	NS
17:0	0.26 \pm 0.017	0.31 \pm 0.017	*
17:1c10	0.27 \pm 0.042	0.28 \pm 0.042	NS
18:0	11.62 \pm 0.165	11.22 \pm 0.165	NS
18:1t9	0.04 \pm 0.002	0.05 \pm 0.002	NS
18:1c9	38.07 \pm 0.653	38.54 \pm 0.653	NS
18:1c7	3.97 \pm 0.077	4.19 \pm 0.077	NS
18:2c9,12 (n-6)	9.48 \pm 0.642	9.91 \pm 0.642	NS
20:0	0.14 \pm 0.006	0.11 \pm 0.006	**
18:3c6,9,12 (n-6)	0.03 \pm 0.010	0.05 \pm 0.010	NS
18:3c9,12,15 (n-3)	0.32 \pm 0.040	0.36 \pm 0.040	NS
20:2c11,14 (n-6)	0.18 \pm 0.009	0.18 \pm 0.009	NS
Behenic	0.01 \pm 0.01	0.03 \pm 0.01	NS
22:0	0.01 \pm 0.009	0.03 \pm 0.009	*
20:3c11,14,17 (n-3)	0.23 \pm 0.030	0.20 \pm 0.030	NS
20:4c5,8,11,14 (n-6)	1.81 \pm 0.220	1.94 \pm 0.220	NS
SFA	42.23 \pm 0.310	41.02 \pm 0.310	*
MUFA	45.72 \pm 0.713	46.44 \pm 0.713	NS
PUFA	12.05 \pm 0.828	12.64 \pm 0.828	NS
n-6	11.49 \pm 0.825	12.08 \pm 0.825	NS
n-3	0.55 \pm 0.031	0.56 \pm 0.031	NS
PUFA:SFA	0.29 \pm 0.022	0.31 \pm 0.022	NS
n-6 : n-3	21.45 \pm 1.550	21.66 \pm 1.550	NS

Significance level: * P < 0.05, ** P < 0.01, *** P < 0.001, NS: not significant.

FFDM: fat-free dry matter, SFA: total saturated fatty acids, MUFA: total monounsaturated fatty acids, PUFA: total polyunsaturated fatty acids, n-6: total omega-6 fatty acids, n-3: total omega-3 fatty acids, c: *cis*, t: *trans*, PUFA : SFA: ratio of polyunsaturated fatty acids and saturated fatty acids, n-6 : n-3: ratio of n-6 : n-3.

This implies that muscle and backfat PUFA : SFA ratios of both breeds in the current study had lower nutritional value for consumers. The PUFA : SFA ratio for LW gilts was better than for WS gilts.

The muscle of both breeds had less n-6 and n-3 than in backfat, in contrast to the report of Wood *et al.* (2008). The proportions for n-6 : n-3 in pork of WS gilts and LW gilts were far higher than the 7.2 reported in muscle by Enser *et al.* (1996). This can be ascribed to the diet pigs were consuming prior to slaughter. In the study, the n-6 : n-3 ratio was about 20 : 71 in finishing diet of pigs. This might have caused a higher n-6 : n-3 proportion in muscle and backfat.

Table 4 Backfat proximate analysis and fatty acid profiles (as a percentage of the total fatty acids identified) (\pm standard errors) for Large White and Windsnyer gilts

Attributes	Breed		Significance
	Windsnyer (n: 12)	Large White (n: 12)	
Proximate analysis			
Extractable fat	77.60 \pm 0.958	74.82 \pm 0.958	*
FFDM	6.97 \pm 0.250	7.60 \pm 0.250	*
Moisture	15.42 \pm 0.989	17.5 \pm 0.989	*
Fatty acids and ratios			
14:0	1.58 \pm 0.023	1.60 \pm 0.023	NS
15:0	0.02 \pm 0.007	0.05 \pm 0.007	**
16:0	29.71 \pm 0.195	28.60 \pm 0.195	***
16:1c9	2.00 \pm 0.083	2.09 \pm 0.083	NS
17:0	0.42 \pm 0.020	0.54 \pm 0.020	***
18:0	14.25 \pm 0.378	13.72 \pm 0.378	NS
18:1t9	0.053 \pm 0.005	0.048 \pm 0.005	NS
18:1c9	37.28 \pm 0.358	37.10 \pm 0.358	NS
18:1c7	2.35 \pm 0.058	2.51 \pm 0.058	NS
18:2c9,12 (n-6)	11.13 \pm 0.256	12.44 \pm 0.256	**
20:0	0.20 \pm 0.007	0.18 \pm 0.007	*
18:3c9,12,15 (n-3)	0.48 \pm 0.030	0.54 \pm 0.030	NS
20:2c11,14(n-6)	0.37 \pm 0.009	0.38 \pm 0.009	NS
20:3c11,14,17 (n-3)	0.01 \pm 0.006	0.03 \pm 0.006	**
20:4c5,8,11,14 (n-6)	0.13 \pm 0.008	0.17 \pm 0.008	***
SFA	46.58 \pm 0.517	44.68 \pm 0.517	*
MUFA	41.69 \pm 0.457	41.74 \pm 0.457	NS
PUFA	12.13 \pm 0.282	13.58 \pm 0.282	***
n-6	11.68 \pm 0.270	13.00 \pm 0.270	**
n-3	0.49 \pm 0.029	0.57 \pm 0.029	*
PUFA:SFA	0.26 \pm 0.008	0.31 \pm 0.008	**
n-6: n-3	24.40 \pm 1.250	23.54 \pm 1.250	NS

Significance level: * P < 0.05, ** P < 0.01, *** P < 0.001, NS: not significant.

FFDM: fat-free dry matter, SFA: total saturated fatty acids, MUFA: total monounsaturated fatty acids, PUFA: total polyunsaturated fatty acids, n-6: total omega-6 fatty acids, n-3: total omega-3 fatty acids, c: *cis*, PUFA: SFA: ratio of polyunsaturated fatty acids and saturated fatty acids, n-6: n-3: ratio of n-6: n-3.

Previous studies have shown that dietary n-6 : n-3 ratio affects the fatty acid profile of the resultant muscle and fat tissues (Huang *et al.*, 2008; Li *et al.*, 2015). A high n-6 : n-3 proportion is undesirable for consumer health. However, various lines of evidence in the literature favour the importance of the n-6 : n-3 ratio, and support the view that decreasing it through dietary manipulation leads to increased protection against degenerative diseases (Russo, 2009). The MUFA proportions in LW and WS pigs were above the range highlighted by Hoffman *et al.* (2004). Ideal MUFA reduces human low density lipoprotein (LDL) cholesterol and increases high density lipoprotein (HDL) cholesterol concentrations and lower the risk of coronary heart disease (Department of Health, 1994).

Conclusions

Overall, the study showed preferential attributes of pork from LW gilts than from WS gilts. Fatty acid profiles showed that there is a need to manipulate the feed given to pigs so that pork can be of good

nutritional value to the consumer. Further research should assess the physico-chemical attributes and fatty acid profiles of pig breeds when fed on forage-based diets.

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Authors' Contributions

JM and MC were involved in the proposal development and funding of the project while AGB and CLFK were involved in management of the pigs until slaughter. VM was the expert in meat science analysis and AH was the expert in fatty acids analysis. All the authors were involved in the write up of the final paper.

Conflict of Interest Declaration

All authors declare that there are no actual or potential conflicts of interest between the authors and other people or organizations that could inappropriately bias their work.

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