Sensory, physical and chemical quality characteristics of bacon derived from South African indigenous and commercial pig breeds

L.C. Hoffman[1#], E. Styger[1,2], M. Muller[2] and T.S. Brand[1,3]
[1]Department of Animal Sciences, [2]Department of Consumer Science, University of Stellenbosch, Private Bag X1, Matieland 7602, South Africa
[3]Elsenburg Agricultural Research Centre, Private Bag X1, Elsenburg 7607, South Africa

Abstract

Sensory and physical quality characteristics of shoulder and leg ham, kassler chops, back and belly bacon derived from South African indigenous Kolbroek (KB), African (AFR) and commercial Landrace X Large White (LR X LW) pig breeds were compared. The chemical quality characteristics were only determined on the ham, kassler chops and bacon derived from the two South African indigenous pig breeds. Breed had a significant influence on the fat, protein and ash content of the shoulder ham, kassler chops and belly bacon. The only significant differences in fatty acid composition between the KB and AFR pigs were found in the less abundant fatty acids including myristic acid (C14:0), eicosadienoic acid (C20:2n-6), γ-linolenic acid (C18:3n-6) and tetracoseanoic acid (C24:1n-9). The minerals calcium, potassium, magnesium and phosphorus of the back and belly bacon differed significantly between the two indigenous pig breeds. The objective colour measurements (L*, a*, b*, hue, chroma) and sensory quality characteristics differed significantly between the two indigenous and commercial (LR X LW) pig breeds. In most of the cases the KB and AFR pigs showed lower L* and higher a* values, indicating a darker and redder meat colour than that of the LR X LW pigs. Regarding the sensory quality characteristics, the KB and AFR pigs showed significantly lower scores for tenderness and juiciness for both the ham and kassler chops compared to those of the LR X LW pigs. In conclusion, although there were breed differences, the two indigenous pig breeds were found to be suitable for commercial processing into ham, kassler chops and back bacon after significant trimming of excess fat. This could open a niche in the market for traditionally produced pork products.

Keywords: Indigenous pig breeds, bacon, sensory attributes, physical quality, chemical composition
[#]Corresponding author. E-mail: lch@sun.ac.za

Introduction

In the last decade changes in consumer preferences have led to a global decrease in fresh meat consumption (Verbeke *et al.*, 1999). The progressive decline in per capita consumption of pork in South Africa can be ascribed to the negative perceptions regarding its nutritional value and fat content (Brewer *et al.*, 2001). Together with the health concerns, meat quality and sensory properties are increasingly important aspects related to meat production and consumption (Verbeke, 2001). More than ever the pig production industry is under pressure to improve the acceptance of pork, particularly with reference to consumer demand for leaner pork. However, the production of leaner pork must be achieved without compromising the final sensory qualities of the product (Bukala & Kedzior, 2001).

Breeds are considered one of the most important distinguishing intrinsic factors influencing the final quality of meat products (Campo *et al.*, 1999). Several investigations have indicated that different pig breeds have different meat quality characteristics (Barton Gade *et al*, 1988; Cameron, 1990; Campo *et al*., 1999). Colour is the first critical sensory quality characteristic and it has been established that variable muscle colour may be linked to different breeds (Fjelkner-Modig & Persson, 1986). Moreover, tenderness is considered as the most important pork quality attribute and breeds are known to have a substantial effect on tenderness (Enfält *et al.*, 1997). Juiciness, as determined by marbling fat or intramuscular fat, is also known to differ amongst breeds (Jeremiah *et al.*, 1999; Cameron *et al.*, 2000; Jonsäll *et al.*, 2002). However, considerable controversy is still evident in the literature on the effect of breed on meat quality characteristics. Also, limited research has been done on the effect of indigenous pig breeds (particularly African breeds) on the eating quality of pork, especially with respect to the sensory quality characteristics. Guy & Edwards (2001) suggested the utilisation of traditional pig breeds, which are well-known for their high levels of marbling fat, in alternative production systems. Indigenous pig breeds have an ability to adapt to their natural environment more efficiently in comparison to other pig breeds such as Duroc and Landrace. However, traditional pig breeds are relatively slow growing and consequently decreased tenderness through proteolytic mechanisms may occur (Warriss *et al.*, 1996).

The success of utilising South African indigenous pig breeds, in particular the so-called Kolbroek (KB) pigs, should be investigated as these breeds appear to be well adapted, easy to handle and do not show any susceptibility to stress (Nicolas, 1999). The latter characteristics may have a positive influence on the sensory quality characteristics of the meat. The origin of the Kolbroek pig breed is not clear, but there is some speculation that the name was derived from the *Coalbrook*, a ship of the British East India Company that was wrecked at Cape Hangklip, close to Betty's Bay, South Africa, in 1778. The ship had pigs on board that were rescued and it is surmised that the name Kolbroek originated from these animals (Nicolas, 1999). These pigs are characterised by their "spotted" colour pattern and there is also a belief that these pig breeds display some similarities to the Chinese pig breeds (*Sus indica*). Another traditional type of pig is the so-called wild pig (*Sus scrofa*), a typical European pig breed, which appears to have great resistance to diseases and also has a high fertility rate (Morkel, 1925). This pig breed is characterised by its brownish trouser colour and long snout. The so-called African (AFR, "Hutvark") pigs exhibit some similarities to the wild pigs in terms of their appearance and behaviour. However, most indigenous pig breeds appear to have substantially more fat than commercial pig breeds (Nicolas, 1999). The extent to which South African indigenous pig breeds are suitable for producing quality meat products is still unknown.

The aim of this study was to compare the sensory, physical and chemical quality characteristics of commercial processed products derived from South African indigenous (KB and AFR pigs) and commercial (LR X LW) pig breeds.

Materials and Methods

Twenty-four South African indigenous pigs were divided equally in two subgroups, the so-called KB and AFR pig breeds, respectively. The pigs were raised at the Elsenburg Agricultural Research Centre from September to November 2000 (Spring, early summer period). The pigs were fed a commercial pig grower diet. Upon reaching the target weight the pigs were handled and slaughtered according to standard procedures (Fisher *et al.*, 2000).

After a chilling period of 24 h the commercial yields of the KB and AFR pigs were processed according to the procedures described by Fisher *et al.* (2000). The removal of the primal cuts (shoulder, belly, back and legs) from the carcasses was done on a stationary band saw. The leg of pork was used for ham processing. The leg was removed by sawing between the last lumbar and first sacral vertebrae perpendicular to the stretched leg. The trotter was removed from the ham at the distal end of the tibia and fibula parallel to the cut made to remove the leg from the carcass. Sawing along the natural midline split the legs. The leg of pork was then derinded, defatted and deboned. The *M. semitendenosus*, *M. semimembranosus* and *M. biceps femoris* were used in the processing of sectioned and formed ham. The shoulder was removed by cutting caudally through the 5th and 6th thoracic vertebrae, with the front trotter removed by cutting through the metacarpal region (at the joint of the carpal bones and the radius and ulna). Sawing along the spinal column split the remaining carcass. Thereafter, the belly was removed from the back by cutting in a line parallel to the spinal column, approximately 18 cm from the spinal column. The right backs were used for bacon manufacturing. The left backs were used for the preparation of the kassler chops. For the latter, skin and some subcutaneous fat were removed manually from the *M. longissimus dorsi* (MLD).

The shoulder, belly and back were processed into bacon according to the standard processing procedures as described in Fisher *et al.* (2000). The shoulder was placed with its skin surface on the deboning table, after which the neck vertebrae and then the neck were removed. The rest of the shoulder was then deboned. The meat was then removed from the subcutaneous fat at the line of separation between muscle and fat. After removal of the ribs, the belly was passed through a derinding machine (Maja derinder) set to a thickness of 8 mm. With regard to the back, a skin and fat layer was removed by hand, leaving a subcutaneous fat layer of less than 20 mm on the meat. After this the vertebrae were removed.

The selected cuts were then injected with a standard brine solution (Table 1). A multi-needle Fomaco injector set between 3.6-3.8 bar air pressure was used for the injection of the brine. This allowed for the calculated gain of 20-22% (Varnam & Sutherland, 1995).

Table 1 The composition of the brine solution used during the processing of the bacon, ham and kassler chops

Constituent	Percentage (%)	Calculated concentration of the end product (%)
Water	86.00	17.202
Commercial phosphate blend[a]	2.485	0.497
NaCl	9.557	1.910
Sugar	1.529	0.306
Ascorbate	0.248	0.050
Nitrite	0.115	0.023
Citric acid	0.057	0.011

[a]TARI P_{22}; supplied by Giulini Chemie GmbH, Postfach 150480, D-67, Ludwigshafen/Rhein

After being injected, the cuts were submerged in a brine bath (containing the same brine solution) to cure at 4 °C for 24 h, hung and subsequently smoked in a Maurer smoker using mahogany wood chips. The following smoking cycle was used for the belly and back bacon: dry at 55 °C for 60 min, smoke at 57 °C for 60 min, dry a further 15 min at 55 °C, smoke a further 30 min at 57 °C and dry again for 15 min at 55 °C. After the smoking process, the cuts were tempered in a blast freezer until an internal temperature of -4 to –6 °C was obtained. The trimmed shoulder, leg bacon and kassler chops were injected with the same brine solution as described. After the same curing period, the shoulder and leg bacon were tumbled for 20 min and packed into a 120 mm diameter collagen casing prior to smoking. The same smoking cycle as described was used for the shoulder and leg bacon. The kassler chops were not tumbled, but smoked after the curing period, utilising the following cycle; dry at 55 °C for 60 min, smoke at 57 °C for 30 min, dry a further 15 min at 55 °C, smoke a further 35 min at 57 °C and then dry again for 15 min at 55°C. The same tempering procedures were used for the kassler chops. The bacon, ham and chops were cooled at 5 °C for a period of 12 h and then frozen (tempered) at –20 °C before being sliced. The kassler chops, shoulder and leg ham were sliced at approximately 7.5 mm thickness (frequently sold as such in South Africa) and the belly and back bacon were sliced at 2.5 mm thickness. Thereafter, the cuts were labelled, vacuum-packed, frozen and stored at –18 °C until further analyses. The percentage yield (%Y) was calculated as the percentage net gain after completion of the process (Fisher, 1995).

The cuts derived from the indigenous pigs were compared to similar cuts obtained from a commercial crossbreed (LR X LW). The same commercial processes as described was used in the preparation of the later cuts in the same processing plant.

Proximate chemical analyses were conducted on the shoulder and leg hams, kassler chops and belly and back bacon of both indigenous pig breeds. A sub-sample of the specific bacon was randomly sampled and homogenised by being passed repeatedly (normally three times) through a 3 mm diameter mincer (Maja derinder) until a homogenous meat/fat mixture was observed (i.e. no muscle could be differentiated by the eye). As consumers consume both the lean meat and the fat of the bacon, both these constituents were minced together and chemically analysed. Total percentages of moisture, protein and ash were determined according to the standard AOAC methods (AOAC, 1997). The protein (N x 6.25) content was determined by the block digestion method (AOAC, 1997) and ashing was done at 500 °C for a period of 5 h. The moisture content was analysed by drying a 2.5 g sample at 100 °C for a period of 24 h. The total fat content was determined by extracting the fat with a 2:1 mixture of chloroform: methanol (Lee *et al.*, 1996).

After the extraction of the lipids, the fatty acid methyl esters (FAME) were prepared according to the procedures published by Morrison & Smith (1964). The FAME were analysed with a gas-liquid chromatograph (Varian Model 3300) equipped with flame ionisation detection and two 30 m fused silica megabore DB-225 columns of 0.53 mm internal diameter (J&W Scientific, Folsom, CA). Gas flow rates were hydrogen 25 mL/min and nitrogen (carrier gas) 5-8 mL/min. The temperature programme was linear at 4 °C/min with initial and final temperatures of 160 °C and 220 °C (held for 10 min), respectively. The injector temperature was 240 °C and the detector temperature 250 °C. The FAME were identified by comparison of the retention times to those of a standard FAME mixture (Nu-Chek-Prep Inc., Elysian, Minnesota).

A wet ashing method was used to prepare the samples for mineral analysis according to Method IIA of Watson (1994) and involves the boiling of the samples in concentrated nitric acid and perchloric acid. The element concentrations were determined by direct current plasma emission spectrometry (Pinta, 1982). The following elements were analysed: calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), sodium (Na) and phosphorus (P).

The cooked (using the same procedure as described below for the sensory analysis) kassler chops, shoulder and leg ham, belly and back bacon derived from the two indigenous and commercial pig breeds were used for the determination of objective meat colour measurements. Three readings per sample were taken 20 min after cooking. Colour was evaluated according to the method described by Honikel (1998) using a Colorgard System 2000 colorimeter (Pacific Scientific, Silver Spring, MD, USA) to determine L*, a* and b* values with L* indicating lightness, a* the red-green range and b* the blue-yellow range. These values were also used to calculate the chroma value and hue angle according to the following equations: chroma = $\sqrt{(a^{*2}+b^{*2})}$ and the hue angle (°) = $\tan^{-1}(b^*/a^*)$.

Sensory quality characteristics were used to compare the products of the two indigenous and commercial pig breeds. The vacuum-packed bacon, ham and kassler chop samples were defrosted at a temperature of 4 to 6 °C for a period of 24 h prior to cooking on their pre-assigned sensory analysis dates. On completion of the cooking process, the bacon, ham and kassler chop samples were cooled for 20 min, placed in waxed paper and chilled at a temperature of 4 to 6 °C for a period of 24 h prior to sensory analyses. The bacon, ham and kassler chop samples were placed on white plates marked with random three-digit codes approximately 30 min before evaluation and then served to the panel at room temperature (21 °C).

Before the cooking commenced, the ham and kassler chop samples (7.5 mm thick) were fully covered with 600 g of cold water using a large AMC Classic saucepan. After boiling point (95 ºC) was reached, the samples were cooked for an additional 30 min, monitoring the temperature of water at approximately 95 °C using an electronic thermometer. The belly and back bacon (2.5 mm thick) were pan-grilled using an electric grilling pan (Pineware, Model Hz 315). One sample from each breed was placed on a pre-heated grilling pan (pre-heated for 5 min at heat setting 3 for the back bacon, pre-heated for 5 min at heat setting 5 for the belly bacon). Each sample was grilled for 2.5 min on each side. The preparation time was standardised to ensure the absence of surface browning.

Descriptive sensory analysis was performed on the bacon, ham and kassler chop samples derived from the two indigenous and commercial pig breeds. The panellists were selected and trained in accordance with the guidelines for the sensory evaluation of meat of the American Meat Science Association (AMSA, 1995) and the generic descriptive analysis technique (Lawless & Heymann, 1998). A trained, seven-member panel evaluated the bacon, ham and kassler chops, each type on four occasions, for the following sensory attributes: colour, odour, flavour and texture. An unstructured line-scale ranging from 0 to 10 cm was used to evaluate the sensory attributes. Table 2 depicts the definitions of the attributes used in the sensory analyses. The panellists were seated in individual booths in a temperature-controlled and light-controlled (artificial daylight) room (AMSA, 1995). Lemon-flavoured distilled water, apple and crackers were given to the panellist between samples to cleanse their palates.

The experiment consisted of a completely randomised design with either two or three treatments. The treatment design for the descriptive sensory analysis and objective colour measurements was a 3x5 factorial with three pig breeds (KB, AFR and LR X LW) and five primal cuts (kassler chops, shoulder and leg ham, belly and back bacon) as factors. The treatment design for the chemical analysis was a 2x5 factorial with two pig breeds (KB and AFR) and five primal cuts (kassler chops, shoulder and leg ham, belly and back bacon) as factors. A factorial analysis of variance was performed on all the data using the SAS Version 8.12 (SAS, 1990). The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). In some cases deviations from normality were the cause of one or two outliners, which were removed before the final analysis. Where there was still significant evidence of non-normality, this could be ascribed to kurtosis rather than skewness. Student's t-Least Significant Difference (LSD) was calculated at a 5% significance level to compare treatment comparison of means (Glass *et al.*, 1972).

Table 2 Description of attributes utilised by the taste panel for the sensory analyses of the shoulder and leg hams, kassler chops and belly and back bacon

Attribute	Scale	Definition
Colour	0 = Greyish pink 10 = Dark pink	Presence of pinkish colour
Odour	0 = Slight smoky odour 10 = Prominent smoky odour	The intensity of a smoky odour perceived by sniffing
	0 = No wild odour; 10 = Prominent wild odour	The presence of a wild-odour perceived by sniffing
Flavour	0 = Slight smoky flavour 10 = Prominent smoky flavour	Typical smoky flavour of cured pork
	0 = Slight salty taste 10 = Prominent salty taste	Typical salty taste of cured pork
	0 = No aftertaste 10 = Prominent aftertaste	The presence of an aftertaste
Texture	[a]0 = Untypical bacon texture 10 = Typical bacon texture	The presence of a typical bacon texture i.e. juicy and tender
	[b]0 = Dry bacon texture 10 = Juicy bacon texture	The degree of juice released while chewing the bacon
	[b]0 = Tough bacon texture 10 = Tender bacon texture	The time needed to masticate the sample before swallowing

[a]Distinctive product characteristics as identified by panel for belly and back bacon
[b]Distinctive product characteristics as identified by panel for shoulder ham

Results and Discussion

The comparison of the means for the percentage yield (%Y) of the bacon, hams and kassler chops derived from the two indigenous pig breeds is presented in Table 3. Breed had no significant ($P > 0.05$) effect on the %Y obtained from the different primal cuts, except for that of the kassler chops. A significantly ($P \leq 0.05$) higher %Y was obtained for the kassler chops of the AFR pigs (15.93%) compared to that of the KB pigs (10.47%). Although not significant, the %Y of the belly bacon was also higher for the AFR pigs (11.03%) than for the KB pigs (8.38%). The KB pigs, however, tended to have a higher %Y for the back bacon, shoulder and leg hams.

Most of the primal cuts that showed the higher %Y during processing (Table 3) also had higher moisture contents as demonstrated in Table 4. The results for the proximate chemical composition (Table 4) of the hams and chops showed significant differences ($P \leq 0.05$) with regard to the fat and ash content of the KB and AFR pigs. For both the shoulder ham and kassler chops the KB pigs had a significantly ($P \leq 0.05$) higher fat content than the AFR pigs. The leg ham of the AFR pigs had a significantly ($P \leq 0.05$) higher ash content than the KB pigs. The results for the bacon showed significant differences ($P \leq 0.05$) with regard to the fat, protein and ash content of the KB and AFR pigs. For the belly bacon the KB pigs had a significantly ($P \leq 0.05$) higher fat content and lower protein content than the AFR pigs. During the processing of the belly bacon, the subcutaneous fat layer of the meat from both the KB and AFR pigs was removed using a derinding machine set at a thickness of 8 mm. The higher fat content (chemically analysed) of the KB pigs can therefore most probably be ascribed to a breed effect. A significantly ($P \leq 0.05$) higher ash content was found in the back bacon of the AFR pigs compared to the KB pigs. Although not significant, the AFR pigs had a higher total fat content in the leg ham than that of the KB. This could possibly be ascribed to the fact that the AFR pigs had more intramuscular fat (IMF) or due to the inconsistent hand-trimming processing techniques that were used for the preparation of the leg ham. The latter is the most probable explanation. Although not significant, there was a tendency for the fat content of all the primal cuts to be inversely related to their moisture and protein content. This tendency is consistent with the results of Keeton (1983), who showed a decrease in protein and moisture content with an increase in fat content of pork patties.

Table 3 Comparison of the mean percentage yield (%) of the shoulder and leg hams, kassler chops, belly and back bacon derived from KB and AFR pig breeds

	Breeds		
	KB	AFR	LSD
Shoulder ham	11.75	8.62	4.20
Leg ham	10.86	10.12	2.02
Kassler chop	10.47[b]	15.93[a]	3.63
Back bacon	13.61	11.71	5.53
Belly bacon	8.38	11.03	3.93

[a,b]Means in the same row with different superscripts are significantly different ($P \leq 0.05$)
LSD = Least Significant Difference ($P = 0.05$)
KB = Kolbroek pigs
AFR = African pigs

The effect of the two indigenous pig breeds on the mineral composition of the meat was relatively minor with significant differences ($P \leq 0.05$) being noted for Ca, K, Mg and P (Table 4) in the back and belly bacon. For the back bacon the KB pigs had a significantly ($P \leq 0.05$) higher K (25.06 mg/100 g meat), but a lower P (253.09 mg/100 g meat) content compared to the K (3.37 mg/100 g meat) and the P (559.46 mg/100 g meat) content of the AFR pigs. On the other hand, for the belly bacon, the AFR pigs had a significantly ($P \leq 0.05$) higher Ca (7.73 mg/100 g meat), K (59.96 mg/100 g meat) and Mg (11.27 mg/100 g meat) content compared to the Ca (6.26 mg/100 g meat), K (37.83 mg/100 g meat) and the Mg (6.51 mg/100 g meat) of the KB pigs. Although not significant, the bacon derived from the AFR pigs had a slightly higher Na content than that of the KB pigs. The higher Na content of the bacon of the AFR pigs (Table 4) appeared to result in a more prominent salty taste compared to the bacon derived from the KB pigs (Table 7). This tendency is consistent with the results of Fisher (1995), who reported that the bacon from halothane-positive pig genotypes with a high sodium content resulted in a very salty taste.

Comparison of the means for the fatty acid composition of the kassler chops, shoulder and leg hams, back and belly bacon derived from the KB and AFR pigs is presented in Table 5. A substantial portion of fatty acids did not differ significantly ($P > 0.05$) between the KB and AFR pigs and this may be attributed to the fact that all the pigs were fed the same commercial diet. This is mainly due to the ability of pigs to incorporate dietary fatty acids directly into their tissue lipids (Warriss, 2000). The fatty acids that did differ significantly at the 5% level can therefore be ascribed to the main effects (breeds). As such, the KB pigs had a significantly ($P \leq 0.05$) higher myristic acid (C14:0) content for the leg ham and a higher eicosadienoic acid (C20:2n-6) content for the shoulder ham than those of the AFR pigs. On the other hand, the AFR pigs had a significantly ($P \leq 0.05$) higher γ-linolenic acid (C18:3n-6) content for the shoulder ham and a higher tetracoseanoic acid (C24:1n-9) content for both the kassler chops and belly bacon. For all the primal cuts, palmitic acid (C16:0) was the most abundant SFA, followed by stearic acid (C18:0) comprising between 35-44% of the total SFA. Oleic acid (C18:1n-9) was the most abundant mono-unsaturated fatty acid (MUFA) and linoleic acid (C18:2n-6) the most abundant PUFA. However, these major fatty acids did not differ significantly ($P > 0.05$) between the two indigenous pig breeds.

Table 5 also demonstrates the ratio of PUFA to SFA in the different primal cuts. According to the dietary guidelines of the British Committee on Medical Aspects of Food and Nutrition Policy (COMA), a PUFA: SFA ratio of >0.45 and <1.0 is recommended (COMA, as cited by Corino *et al*., 2002). It can be deduced that all the PUFA: SFA ratios are far below the recommended value of >0.45 and <1.0. This can be explained by the overall low content of linoleic acid (C18:2n-6), the main contributor to the total PUFA content. Manipulating the fatty acid content of the diet could change this ratio (Rosenvold & Andersen, 2003). However, it is not clear what the effect of this manipulation would be on the perceptions of the consumer if the indigenous pig breeds were to be marketed as “natural and indigenous, out of Africa”.

The colour (CIELab) of the processed products derived from the two indigenous pig breeds were evaluated and compared with that of the commercial (Landrace X Large White) hybrids (Table 6). For both the shoulder and leg ham, the KB pigs had the lowest chroma and L* values indicating the darkest meat colour, but only differed ($P \leq 0.05$) from the LR X LW pigs. Also, for the shoulder ham the KB pigs had the highest ($P \leq 0.05$) hue angle and a* value indicating redder and a more yellow meat colour than that of the LR X LW pigs.

The results for the kassler chops showed that the AFR pigs had the lowest ($P \leq 0.05$) chroma and L* value, but the highest ($P \leq 0.05$) hue angle, a* and b* values. These results indicate a darker, redder and a more yellow meat colour compared to that of the LR X LW pigs. Results of Townsend *et al*. (1978) showed that meat from wild pigs had a darker appearance and improved redness (Hunter colour scores) compared to Yorkshire or the cross between the two. In the present investigation the results of the bacon cuts showed that the AFR pigs had the lowest ($P \leq 0.05$) L* value, indicating a darker meat colour than both the KB and LR X LW pigs.

According to Brewer & McKeith (1999), L* values correlate with the pink and/or red colour of pork loin samples. In the present investigation it can be deduced that the L* and a* values obtained from the different cuts are consistent with the results of the sensory colour characteristic, though not significant. The lower L* and higher a* values of the meat is consistent with the darker pink colour as perceived by the taste panel (Table 7).

One of the objectives for this investigation was to determine the suitability of the two indigenous pig breeds for commercial processing into bacon, ham and kassler chops. Bacon, ham and kassler chops derived from these two breeds were therefore compared to similar products derived from commercial (LR X LW) hybrids. Comparison of the means for the sensory quality characteristics of the kassler chops, shoulder and leg ham, back and belly bacon is presented in Table 7. It can be deduced that for all the primal cuts the significant differences ($P \leq 0.05$) were only found between the KB or AFR and the LR X LW pig breeds, but not between the two indigenous pig breeds. The results for the shoulder ham showed significant differences ($P \leq 0.05$) with regard to colour, salty taste and juiciness. The shoulder ham from the KB pigs had the highest score ($P \leq 0.05$) for dark pink colour, but the lowest score for salty taste and intermediate score for juiciness. For the leg ham, the KB pigs had a significantly ($P \leq 0.05$) more prominent wild odour than that of the LR X LW pigs. The kassler chops of the different pig breeds also differed significantly ($P \leq 0.05$) with regard to aftertaste and tenderness. The KB pigs had significantly ($P \leq 0.05$) the most prominent aftertaste and had a lower score for tenderness compared to that of the LR X LW pigs. Similar findings were obtained from Okubanjo (1998), who reported substantially lower tenderness scores for the Nigerian indigenous pig breeds compared to those of the Large White, Duroc and Landrace pig breeds.

The bacon cuts of the different breeds also differed significantly ($P \leq 0.05$) with regard to colour, smoky flavour, salty taste, aftertaste and bacon texture. For the back bacon the KB pigs had the highest score ($P \leq 0.05$) for salty taste, intermediate score for smoky flavour and lowest score for dark pink colour. The back bacon from the KB pigs had a significantly ($P \leq 0.05$) more prominent grey-pink colour compared to that of the LR X LW pigs. This finding corresponds with the results of Okubanjo (1998), who concluded that the *M. longissimus* from the Nigerian indigenous pig breeds had a uniformly greyish pink colour compared to that of the Duroc and Landrace pig breeds. For the belly bacon the KB pigs had the highest score ($P \leq 0.05$) for typical bacon odour, salty taste, aftertaste and typical bacon texture, but scored intermediate for dark pink colour and lowest for smoky flavour.

It is generally accepted that marbling or intramuscular fat (IMF) positively correlates with the sensory quality characteristics (tenderness, juiciness, flavour) of pork (Mullan & D’Souza, 2000; Lin & Chuang, 2001; Brewer *et al*., 2001). However, the results of the present investigation failed to substantiate an association between the fat content and sensory quality characteristics of the bacon, ham and chops from the KB and AFR pigs. This observation is supported by the data of Casteels *et al*. (1995), who found no positive relationship between the eating quality and IMF levels of three pig genotypes.

Table 4 Comparison of the means for the proximate chemical (g/100 g meat sample) and mineral (mg/100 g meat sample) composition of the shoulder and leg ham, kassler chops, back and belly bacon between the KB and AFR pigs

Chemical constituent	Shoulder ham			Leg ham			Kassler chops			Back bacon			Belly bacon		
	KB	AFR	LSD	KB	AFR	LSD	KB	AFR	LSD	KB	AFR	LSD	KB	AFR	LSD
Moisture	59.60	67.93	29.69	72.76	72.37	6.41	51.07	57.33	8.67	45.78	45.63	9.79	43.98	45.41	3.48
Fat	25.77[a]	13.63[b]	4.57	6.64[a]	8.16[a]	8.92	37.20[a]	29.27[b]	1.87	38.38[a]	37.85[a]	1.09	45.22[a]	39.32[b]	4.64
Protein	10.26	15.07	8.91	18.23	15.99	3.45	10.35	12.25	4.20	8.63	11.80	9.11	7.70[b]	11.11[a]	1.82
Ash	3.08	3.31	5.52	2.38[b]	3.34[a]	0.71	4.25	3.41	2.07	3.71[b]	3.91[a]	2.74	3.32	3.76	0.77
Ca	2.59	3.30	8.07	2.43	2.69	1.57	12.04	14.91	7.21	5.86	tr[c]	NC[d]	6.26[b]	7.73[a]	1.23
Fe	0.42	1.03	3.88	1.14	0.78	2.10	1.12	1.15	1.48	3.18	4.97	3.56	1.61	1.68	1.46
K	tr[c]	2.39	NC[d]	1.44	2.66	3.10	58.80	58.70	59.49	25.06[a]	3.37[b]	19.43	37.83[b]	59.96[a]	12.17
Mg	11.51	16.86	11.41	21.18	19.85	5.65	11.06	14.75	5.12	9.29	tr[c]	NC[d]	6.51[b]	11.27[a]	2.19
Na	313.15	423.72	948.62	367.44	388.41	150.10	311.14	323.08	163.96	464.13	432.25	55.90	465.99	394.57	165.51
P	677.01	864.63	312.73	858.46	887.02	284.26	229.49	435.60	404.14	253.09[b]	559.46[a]	78.16	244.78	85.14	48.02

[a,b]Means in the same row with different superscripts are significantly different ($P \leq 0.05$)
[c]tr = trace = <0.001 mg/100 g meat sample
[d]NC = Not Calculated
LSD = Least Significant Difference (P = 0.05)
KB = Kolbroek pigs
AFR = African pigs

Table 5 Comparison of the means for the fatty acid composition of the shoulder and leg hams, kassler chops, back and belly bacon between the KB and AFR pigs (% by weight of total fatty acids)

	Shoulder ham			Leg ham			Kassler chops			Back bacon			Belly bacon		
	KB	AFR	LSD	KB	AFR	LSD	KB	AFR	LSD	KB	AFR	LSD	KB	AFR	LSD
C14:0	1.26	1.27	7.15	1.58[a]	0.84[b]	0.27	0.77	0.75	0.50	1.13	1.02	0.33	0.81	0.82	0.22
C16:0	25.47	25.35	38.51	26.76	22.48	12.01	26.30	25.70	2.87	25.14	25.03	3.79	24.13	24.12	2.21
C18:0	13.83	15.45	36.86	14.36	15.34	10.69	21.28	20.52	7.73	16.86	16.85	3.93	17.36	17.81	1.83
C20:0	0.05	0.31	1.65	0.27	0.28	0.43	0.06	0.00	0.25	0.13	0.16	0.25	0.29	0.32	0.37
C22:0	0.00	0.05	1.21	0.05	0.00	0.19	0.01	0.01	0.03	0.03	0.04	0.05	0.01	0.05	0.09
C24:0	0.03[a]	0.00[b]	0.00	0.00	0.13	0.54	0.06	0.08	0.13	0.02	0.05	0.08	0.05	0.12	0.12
C16:1n-7	3.93	2.74	3.74	3.45	1.98	4.94	2.07	1.57	1.26	2.47	2.52	0.74	2.36	2.83	0.66
C18:1n-9	49.14	45.89	22.00	43.50	45.66	10.52	42.69	43.65	8.70	43.11	44.84	2.97	43.74	41.46	3.03
C20:1n-9	1.25	1.43	3.74	1.32	1.74	1.11	1.91	1.66	0.66	1.68	1.64	0.71	1.73	1.50	0.28
C24:1n-9	0.05	0.06	0.11	0.07	0.28	0.90	0.01[b]	0.25[a]	0.03	0.06	0.16	0.15	0.00[b]	0.12[a]	0.10
C18:2n-6	3.48	5.13	19.15	5.56	5.99	0.53	3.00	3.73	0.95	6.82	4.74	4.18	5.77	7.08	3.04
C18:3n-6	0.01[b]	0.13[a]	0.00	0.16	0.17	0.30	0.01	0.01	0.06	0.15	0.10	0.12	0.17	0.12	2.52
C18:3n-3	0.39	0.37	0.33	0.54	1.37	3.84	0.62	0.81	0.45	0.39	0.63	0.24	0.74	0.74	0.19
C20:2n-6	0.56[a]	0.24[b]	0.11	0.34	0.71	1.08	0.48	0.67	0.42	0.38	0.44	0.16	0.49	0.51	0.21
C20:3n-6	0.08	0.08	0.11	0.11	0.21	0.43	0.12	0.15	0.28	0.21	0.30	0.41	0.51	0.44	0.57
C20:4n-6	0.31	0.24	0.99	0.33	0.52	0.89	0.24	0.24	0.15	0.44	0.52	0.26	0.37	0.38	0.22
C20:3n-3	0.00	0.23	0.99	0.25	0.45	1.29	0.02	0.00	0.07	0.16	0.03	0.14	0.18	0.05	0.19
C20:5n-3	0.06	0.05	0.11	0.07	0.20	0.60	0.13	0.02	0.30	0.14	0.17	0.18	0.15	0.35	0.28
C22:2n-6	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.01	0.09	0.10	0.21	0.25	0.21	0.27
C22:4n-6	0.00	0.51	1.54	0.74	0.92	0.62	0.03	0.00	0.13	0.12	0.22	0.26	0.26	0.21	0.31
C22:5n-3	0.00	0.24	1.76	0.22	0.50	0.71	0.14	0.22	0.10	0.24	0.32	0.21	0.32	0.40	0.25
C22:6n-3	0.11	0.28	0.22	0.36	0.27	0.61	0.08	0.01	0.09	0.22	0.16	0.12	0.30	0.36	0.27
SFA	40.64	42.43	8.47	43.00	39.06	18.33	48.47	47.05	9.64	43.31	43.14	6.38	42.65	43.24	2.70
MUFA	54.37	50.12	22.12	48.35	49.65	11.47	46.66	47.11	9.55	47.32	49.15	3.20	47.84	45.92	3.04
PUFA	4.99	7.47	13.54	8.66	11.30	6.92	4.87	5.84	1.03	9.36	7.71	4.39	9.51	10.85	3.71
PUFA:SFA	0.12	0.18	0.26	0.20	0.30	0.21	0.10	0.13	0.18	0.24	0.18	0.11	0.23	0.26	1.77

[a,b]Means in the same row with different superscripts are significantly different ($P \leq 0.05$)
LSD = Least Significant Difference (P = 0.05)
KB = Kolbroek pigs
AFR = African pigs
SFA = Saturated fatty acids
MUFA = Mono-unsaturated fatty acids
PUFA = Polyunsaturated fatty acids
PUFA:SFA = Ratio of polyunsaturated to saturated fatty acid

Table 6 Comparison of the means for the objective colour measurements (L*, a*, b*, hue, chroma) of the shoulder and leg ham, kassler chops, back and belly bacon between the two indigenous (KB and AFR pigs) and commercial (LR X LW) pig breeds

Colour	Shoulder ham				Leg ham				Kassler chops				Back bacon				Belly bacon			
para-meter	KB	AFR	LR X LW	LSD	KB	AFR	LR X LW	LSD	KB	AFR	LR X LW	LSD	KB	AFR	LR X LW	LSD	KB	AFR	LR X LW	LSD
L*	51.30^{a}	51.78^{b}	60.22^{a}	2.57	55.16^{b}	56.19^{b}	59.06^{a}	2.52	61.53^{b}	59.00^{b}	67.28^{a}	3.50	62.11^{a}	58.76^{a}	60.37^{a}	3.73	52.24^{a}	48.96^{a}	50.97^{a}	3.99
a*	11.71^{a}	11.12^{ab}	9.92^{b}	1.22	10.49	9.60	10.69	1.59	8.82^{ab}	9.15^{a}	7.39^{b}	1.50	6.86	7.60	8.01	1.74	8.85	10.38	10.63	2.07
b*	11.13	12.00	11.32	1.09	11.52	12.20	11.22	1.99	14.61^{b}	15.95^{a}	10.73^{c}	1.28	13.53^{a}	11.47^{b}	11.45^{b}	1.22	14.92^{a}	13.05^{b}	11.70^{b}	1.68
Hue	0.23^{a}	0.21^{a}	0.16^{b}	0.03	0.19	0.17	0.18	0.03	0.15^{a}	0.15^{a}	0.11^{b}	0.03	0.11	0.13	0.13	NS^{c}	0.17	0.21	0.21	0.05
Chroma	52.62^{b}	52.98^{b}	61.03^{a}	2.36	56.16^{b}	57.02^{b}	60.04^{a}	2.30	62.17^{b}	59.72^{b}	67.69^{a}	3.30	62.51	59.25	60.90	3.58	52.99	50.09	52.08	3.65

^{a,b}Means in the same row with different superscripts are significantly different ($P \leq 0.05$)
^{c}NS = Not Significant ($P > 0.05$)
LSD = Least Significant Difference ($P = 0.05$)
KB = Kolbroek pigs
AFR = African pigs
LR X LW = Landrace x Large White pigs

Table 7 Comparison of the means for the sensory quality characteristics of shoulder and leg ham, the kassler chops, back and belly bacon between the two indigenous (KB and AFR pigs) and commercial (LR X LW) pig breed

	Shoulder ham				Leg ham				Kassler chops				Back bacon				Belly bacon			
	KB	AFR	LR X LW	LSD	KB	AFR	LR X LW	LSD	KB	AFR	LR X LW	LSD	KB	AFR	LR X LW	LSD	KB	AFR	LR X LW	LSD
Colour	7.69^{a}	7.06^{a}	5.91^{b}	0.90	7.39	7.10	6.41	1.57	6.57	7.37	6.58	1.18	4.56^{b}	5.96^{ab}	7.13^{a}	1.67	7.83^{ab}	8.26^{a}	7.48^{b}	0.73
Smoky odour	7.29	7.18	6.97	0.88	7.57	7.52	7.59	0.71	8.36^{a}	8.49^{a}	7.68^{b}	0.48	5.58	6.32	5.88	1.47	4.51^{b}	5.35^{a}	5.06^{ab}	0.81
Wild odour	2.28	2.28	1.74	1.37	2.36^{a}	1.75^{ab}	0.76^{b}	1.19	1.26	1.25	1.09	1.42	5.27	4.07	3.48	2.13	6.50^{a}	5.12^{b}	4.15^{b}	1.16
Smoky flavour	7.41	7.04	7.26	0.74	7.20	7.79	7.58	0.75	8.13	8.45	8.05	0.44	7.38^{a}	7.67^{a}	6.71^{b}	0.52	6.95^{b}	7.24^{b}	7.63^{a}	0.38
Salty taste	6.62^{b}	7.06^{ab}	7.58^{a}	0.84	7.06	7.47	7.30	0.74	8.23	8.54	8.24	0.44	8.95^{a}	8.38^{a}	6.58^{b}	0.63	8.80^{a}	8.36^{ab}	7.81^{b}	0.88
After-taste	1.84	2.22	1.51	1.77	2.31	2.45	1.59	1.91	1.89^{a}	1.65^{ab}	1.42^{b}	0.35	3.88	3.57	1.37	2.75	4.11^{a}	2.40^{ab}	1.55^{b}	1.84
Bacon texture	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	1.42	1.51	1.28	1.10	1.62^{a}	1.44^{ab}	0.89^{b}	0.66
Juici-ness	6.32^{ab}	6.19^{b}	7.65^{a}	1.43	6.55	6.75	7.17	1.00	7.20	7.40	7.95	1.18	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}
Ten-derness	6.45	6.62	7.94	2.33	7.43	7.19	7.78	1.00	7.70^{b}	7.20^{b}	8.72^{a}	0.73	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}	NE^{c}

^{a,b}Means in the same row with different superscripts are significantly different ($P \leq 0.05$)
^{c}NE = Not Executed
LSD = Least Significant Difference (P = 0.05)
KB = Kolbroek pigs
AFR = African pigs
LR X LW = Landrace x Large White pigs

Conclusion

One of the objectives for this investigation was to determine the suitability of South African indigenous pig breeds for commercial processing into bacon, ham and chops. In view of the increasing importance of health aspects, chemical analyses were also conducted. Results obtained in this study indicated that the two indigenous pig breeds had a relatively minimal effect on the chemical composition of the bacon, ham and chops. Significant differences were found with regard to the fat, protein and ash content of the different primal cuts. The effect of the two indigenous breeds on the fatty acid composition was also minor, with significant differences only in the less abundant fatty acids. Furthermore, the mineral composition of only the back and belly bacon was significantly influenced by the two indigenous pig breeds. The present results also indicated that the sensory quality characteristics and objective colour measurements differed significantly only between the LR X LW and the KB or AFR pig breeds.

It can therefore be concluded that, even though there were breed differences, the two indigenous breeds were found to be suitable for commercial processing into bacon, ham and chops. This can therefore open a niche in the market for traditionally produced pork products. However, the higher fat content of the two indigenous pig breeds compared to other commercial pig breeds can be seen as unacceptable by health-conscious consumers. To overcome this negative perception, further investigations can be considered to produce leaner meat products derived from South African indigenous pig breeds.

Acknowledgements

This study was partly funded by the Elsenburg Agricultural Research Centre and by a grant from the Technology and Human Research for Industry Program of the Department of Trade and Industry of South Africa. A.C.M. Kruger and technical personnel from the Elsenburg Agricultural Research Centre are thanked for management and care of the animals.

References

AMSA,1995. Guidelines for cookery and sensory evaluation of meat. Chicago, IL: American Meat Science Association, National Livestock and Meat Board.

AOAC, 1997. Official method of analysis. (16th ed.). Arlington, VA: Association of Official Analytical Chemists, Inc.

Barton Gade, P.A., Cross, H.R., Fones, J.M. & Winger, R.J., 1988. Factors affecting sensory properties of meat. In: World animal science, meat science, milk science and technology. Eds. Cross, H.R. & Overby, A.J., New York: Elsevier Science Publishers.

Brewer, M.S. & McKeith. F.K.. 1999. Consumer-related quality characteristics as related to purchase intent of fresh pork. J. Food Sci., 64, 171-174.

Brewer, M.S., Zhu, L.G. & McKeith, F.K., 2001. Marbling effects on quality characteristics of pork loin chops: consumer purchase intent, visual and sensory characteristics. Meat Sci. 59, 153-163.

Bukala, J. & Kedzior, W., 2001. Consumer criteria of quality of meat and meat products. In Proc. 47th Int. Congr. Meat Science and Technology, 26-31 August 2001, Kraków. pp. 262-263.

Cameron, N.D., 1990. Genetic and phenotypic parameters for carcass traits, meat and eating quality traits in pigs. Livest. Prod. Sci. 26, 119-135.

Cameron, N.D., Enser, M., Nute, G.R., Whittington, F.M., Penman, J.C., Fisken, A.C., Perry, A.M. & Wood, J.D., 2000. Genotype with nutrition interaction on fatty acid composition of intramuscular fat and the relationship with flavour of pig meat. Meat Sci. 55, 187-195.

Campo, M.M., Sañudo, C., Panea, B., Alberti, P. & Santolaria, P., 1999. Breed type and ageing time effects on sensory characteristics of beef strip loin steaks. Meat Sci. 51, 383-390.

Casteels, M., Van Oeckel, M.J., Boschaerts, L., Spincemaille, G. & Boucqué, C.V., 1995. The relationship between carcass, meat and eating quality of three pig genotypes. Meat Sci. 40, 253-269.

Corino, C., Magni, S., Pagliarini, E., Rossi, R., Pastorelli, G. & Chiesa, L.M., 2002. Effects of dietary fats on meat quality and sensory characteristics of heavy pig loins. Meat Sci. 60, 1-8.

Enfált, A.-C., Lundström, K., Hansson, I., Lundeheim, N. & Nyström, P.-E., 1997. Effects of outdoor housing and sire breed (Duroc or Yorkshire) on carcass composition and sensory and technological meat quality. Meat Sci. 45, 1-15.

Fisher, P., 1995. Carcass and meat quality characteristics of three halothane genotypes in pigs. M. Sc. Agric. dissertation, University of Stellenbosch, South Africa.

Fisher, P., Mellett, F.D. & Hoffman, L.C., 2000. Halothane genotype and pork quality. I. Carcass and meat quality characteristics of three halothane genotypes. Meat Sci. 54, 97-105.
Fjelkner-Modig, S. & Persson, J., 1986. Carcass properties as related to sensory properties of pork. J. Anim. Sci. 63, 102-113.
Glass, G.V., Peckham, P.D. & Sanders, J.R., 1972. Consequences of failure to meet assumptions underlying the fixed effects analyses of variance and covariance. Rev. Educ. Res. 42, 237-288.
Guy, J.H. & Edwards, S.A., 2001. Consequences for meat quality of producing pork under organic standards. Second International Virtual Conference on Pork Quality. pp. 1-11.
Honikel, K.O., 1998. Reference methods for the assessment of physical characteristics of meat. Meat Sci. 49, 447-457.
Jeremiah, L.E., Gibson, J.P., Gibson, L.L., Ball, R.O., Aker, C. & Fortin, A., 1999. The influence of breed, gender, and PSS (Halothane) genotype on meat quality, cooking loss and palatability of pork. Fd. Res. Intern. 32, 59-71.
Jonsäll, A., Johansson, L., Lundström, K., Andersson, K.H., Nilsen, A.N. & Risvik, E., 2002. Effects of genotype and housing system on sensory characteristics and preference for pork (M. longissimus dorsi). Fd. Qual. Pref. 13, 73-80.
Keeton, A., 1983. Effects of fat and NaCl/Phosphate levels on the chemical and sensory properties of pork patties. J. Food Sci. 48, 878-881, 885.
Lawless, H.T. & Heymann, H., 1998. Sensory evaluation of food: principals and practices. New York: Chapman and Hall.
Lee, C.M., Trevino, B. & CHaiyawat, M., 1996. A simple and rapid solvent extraction method for determining total lipids in fish tissue. J. AOAC. Int. 79, 487-492.
Lin, K.W. & Chuang, C.H., 2001. Effectiveness of dipping with phosphate, lactate and acetic acid solutions on the quality and shelf-life of pork loin chops. J. Feed Sci. 66 (3), 494-499.
Morkel, W.A.K., 1925. Varkboerdery. I. Oorsprong en tiepies. Joernal van die Departement van Landbou, Junie 1925, Pretoria.
Morrison, W.R. & Smith, M.L., 1964. Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride-methanol. J. Lipid Res. 5, 600-602.
Mullan, B.P. & D'Souza, D.N., 2000. Management strategies to optimise the production of quality pork from male pigs. Canberra, Australia: Pig Research and Development Corporation.
Nicolas, G., 1999. Kolbroek – the unique local breed. Farmer's weekly, August.
Okubanjo, A., 1998. Carcass characteristics and quality attributes of the Nigerian and three exotic breeds of pigs. J. Feed Sci. Technol. 35, 83-86.
Pinta, M., 1982. Modern methods for trace element analysis. (3rd ed.). Ann Arbor, MI: Ann Arbor Science.
Rosenvold, K. & Andersen, H.J., 2003. Factors of significance for pork quality – a review. Meat Sci. 64, 219-237.
SAS. 1990. SAS / STAT User's guide, Version 8.1. (4th ed.). Cary, NC: Institute, Inc., USA.
Shapiro, S.S. & Wilk, M.S., 1965. An analysis of variance test for normality (complete samples), Biometrika 52, 591-611.
Townsend, W.E., Brown, W.L., McCampbell, H.C. & Davis, C.E., 1978. Comparison of chemical physical and sensory properties of loins from Yorkshire, crossbreed and wild pigs. J. Anim. Sci. 46, 646-650.
Varnam, A.H. & Sutherland, J.P., 1995. Meat and meat products: technology, chemistry and microbiology. London: Chapman and Hall.
Verbeke, W., 2001. Fresh meat consumption and food safety: behaviour of Belgium consumers. Second International Virtual Conference on Pork Quality. pp. 1-7.
Verbeke, W., Van Oeckel, M.J., Warnants, N., Viaene, J. & Boucque, C.V., 1999. Consumer perception, facts and possibilities to improve acceptability of health and sensory characteristics of pork. Meat Sci. 53, 77-99.
Warriss, P.D., Kestin, S.C., Brown, S.N. & Nute, G.R., 1996. The quality of pork from traditional pig breeds. Meat Focus Intern. 179-182.
Warriss, P.D., 2000. Meat Science. An introductory text. New York: CABI Publishing.
Watson, C., 1994. Official and standardized methods of analysis (3rd ed.). The Royal Society of Chemistry, Cambridge.