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Preslaughter practices, pork physicochemical attributes and fatty acid profiles of pigs raised and slaughtered on smallholder urban farms in the Cape Metropole, South Africa

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ABSTRACT

Pre-slaughter practices, pork physicochemical quality, and fatty acid (FA) composition of 36 Landrace barrows aged six months, sourced from five smallholder urban farms (SUFs) in low-income, high-density suburbs and one commercial abattoir in Cape Metropole District, South Africa were evaluated. Pigs on SUFs were fed three diets: (1) kitchen-bakery-vegetable waste-based, (2) bakery-dairy waste-based, or (3) homemade grain-based, while those on a large-scale farm were fed a commercial diet. Pigs on SUFs were either stunned mechanically or not stunned before slaughter. The SUFs either practiced throat or cervical spine sticking during slaughter. Carcasses from pigs fed the homemade grain-based diet had higher ($P \leq 0.05$) weights, ash subcutaneous and intramuscular fat (IMF) values than those fed the other diets. The homemade grain-based diet, throat sticking treatment produced pork with the highest pH_{45} followed by the bakery-dairy waste-based diet, throat sticking and kitchen-bakery-vegetable waste-based diet, cervical spine treatments ($P \leq 0.05$). Pigs fed a commercial diet and slaughtered by throat sticking produced pork with the lower ($P \leq 0.05$) values for pH_{24}, colour coordinates (L*, a*, b*, H° and C°) and the higher ($P \leq 0.05$) carcass temperature and shear force values relative to the other treatments. Pork from pigs fed the homemade grain-based diets had higher ($P \leq 0.05$) contents of total FA, total PUFA, individual and total *n*-6 PUFA than pork from pigs fed the other diets. Pig carcasses stunned with a gun had higher ($P \leq 0.05$) pH_{45}, pH_{24} and shear force values than those not stunned. The homemade grain-based diet improved carcass attributes and fatty acid profiles of pigs raised and slaughtered on SUFs, stunning enhanced pork physical quality attributes while the kitchen-bakery-vegetable waste-based diet, cervical spine sticking treatment produced less desirable pork physical attributes.

1. Introduction

Smallholder urban pig production is crucial for supplying low-income households with nutritious food, income, and employment (Mathobela et al., 2024; Molotsi et al., 2021). Specifically, pork is a rich source of protein, energy, long-chain fatty acids, minerals, and B vitamins critical for human nutrition, health, and well-being (De Smet & Van Hecke, 2024; Yi et al., 2023). Notably, pork is as an outstanding source of thiamine (i.e., vitamin B1), an antineuritic factor relative to other red meats (Gochhayat et al., 2019; Hamill & Botineştean, 2015). It is also a good source of human health-enhancing bioactive compounds such as creatine, choline, glutathione, and taurine (Beal et al., 2023; Jairath et al., 2024). Smallholder urban pig farmers generate cash mainly through sales of live pigs, carcasses, and pork meat (Mathobela et al., 2024; Shyaka et al., 2022). The smallholder urban pig farming enterprise provides employment and entrepreneurship opportunities to

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traders, slaughterhouses, distributors, processors, marketers, and input suppliers along the pig production continuum (Mathobela et al., 2024; Molotsi et al., 2021; Shyaka et al., 2022).

Pork production and consumption in the cities are trending in the same direction as the increase in urbanisation and urban population (BFAP, 2021; Mohakud et al., 2020). The rise in pork consumption relative to other meats is primarily driven by its versatility and affordability, and positive consumer views and preferences influenced by rising incomes (DALRRD, 2021). Specifically, consumers are becoming more interested in fresh, wholesome, tender, juicy, flavoursome, shelf-stable, safe, healthy, and sustainably-produced meat products (Kasprzyk et al., 2015; Spada et al., 2024). In this context, safety, wholesomeness, healthfulness and sustainability attributes influence meat consumers before purchasing meat (Schrobback et al., 2023). Meat colour and fatness are the most important attributes that influence consumers at the point of purchase, affecting the decision to purchase (King et al., 2023; Testa et al., 2021). Tenderness, flavour and juiciness of meat largely influence consumers upon consumption and impact consumer satisfaction, repeat purchase intention and willingness to pay premium prices (Cardona et al., 2023; Warner et al., 2021).

Pork quality in smallholder urban farming areas remains a concern as most farmers handle, transport and slaughter pigs inhumanely and market pork informally without following appropriate hygiene and safety practices (Baltenweck et al., 2018; Magqupu et al., 2024a). Since appropriate slaughtering standards are only enforced in licensed abattoirs, smallholder pig farmers frequently fall short of the minimal requirements for supplying pigs to such abattoirs and, therefore, opt to slaughter and market their animals informally (Magqupu et al., 2023; Mathobela et al., 2024). Pigs from smallholder urban farms (SUFs) often receive inadequate, imbalanced, and diverse diets, experience high levels of stress due to mishandling prior to slaughter, and are slaughtered using inappropriate stunning and sticking methods, which adversely influences pork quality (Njoga et al., 2023; Sentamu et al., 2022). To the authors' knowledge, the quality of pork from pigs raised and slaughtered on SUFs in developing countries like South Africa has not been investigated. Such information could benefit the meat industry and public health initiatives addressing urban consumers' meat quality and safety concerns in developing countries (Magqupu et al., 2023; Magqupu et al., 2024b). Therefore, the objective of this study was to document preslaughter practices and evaluate the physicochemical quality and fatty acid (FA) composition of pork from pigs raised and slaughtered on SUFs in the Cape Metropole District, South Africa.

2. Materials and methods

2.1. Study site

The research was carried out in five low-income, high-density suburbs, namely IthembaLab (GPS coordinates: −34.020630, 18.711254), Khayelitsha (−34.040539, 18.714261), Mfuleni (−34.008137, 18.675448), Penhill (−33.973532, 18.717577) and Strand (−34.129302, 18.881187) in the Cape Metropole District of the Western Cape Province, South Africa. Farmers were purposively selected from the five suburbs based on ownership of high numbers of barrows ready for slaughter and willingness to participate in the study. Informed consent was sought from all the farmers participating in this study prior to commencing the study in February 2022.

2.2. Animal selection and design

Thirty Landrace barrows aged six months with a body condition score (BCS) of 3.0 were sourced from the Cape Metropole District's five low-income, high-density suburbs. The price for a six-month-old barrow at the time of slaughter was R1 500 (≈ US$80.00). In each suburb, six pigs from one SUF were slaughtered on-farm by the farmer following their regular slaughter practices. This was the maximum number of pigs each farm could provide at the time of slaughter. An additional six Landrace barrows aged six months with 3.0 BCS were sourced from a large-scale commercial farmer feeding a commercially manufactured complete pig finishing diet and slaughtered at a commercial abattoir in Cape Town to serve as the control group. The BCS of pigs were evaluated on a scale of 0 to 5, defined as 0 = emaciated, 1 = poor, 2 = moderate, 3 = good, 4 = fat, and 5 = grossly fat (Holness, 1991).

2.3. Pig feed resources and chemical composition

Samples of feedstuffs offered to pigs were collected from each SUF at the time of slaughter. Five, 1.0 kg feed samples were collected from each farm in designated zip-lock plastic bags [Melbro Wholesale (Pty) Limited, China] and transported to the Stellenbosch University Animal Nutrition Laboratory for nutrient analysis. The Association of Official Analytical Chemists (AOAC, 2016) protocols 950.46, 991.36 and 920.153 were used to determine the dry matter (DM), ether extract (EE), and ash, respectively. The Dumas combustion method (992.15; AOAC, 2016) was used to calculate crude protein (CP) content using the LECO® FP 828 (LECO, St. Joseph, MI, USA) nitrogen analyser. The 6.25 factor was used for the nitrogen-to-protein conversion. Crude fibre (CF) exclusive of residual ash was determined using the ANKOM^{220} Fibre Analyser (Ankom Technology Corp., Fairport, NY, USA). To determine the gross energy, a compact semi-automated combustion calorimeter (IKA® C200 Oxygen Bomb Calorimeter, CP 00 Bomb Calorimeter, Wilmington, NC, USA) was used. Each feed sample was analysed in duplicate. For FA composition of the feed resources, the samples were analysed following the approach described by Sukhija and Palmquist (1988). In summary, 0.1 g of feed samples was extracted with 2 mL of *n*-hexane. Details of methylation, instrument conditions, temperature settings, identification, and quantification were described by Uushona et al. (2021).

2.4. Pig preslaughter practices on SUFs

Slaughter weights of pigs on SUFs were measured using a fabric measuring tape (Rondo, Kyron Laboratories (Pty) Ltd, South Africa) according to Al Ard Khanji et al. (2018). Preslaughter feeding, handling, stunning, sticking, exsanguination, scalding, dehairing, evisceration, and carcass storage practices of the SUFs and commercial abattoir were captured. Pigs on SUFs were fed one of the three diets: (1) kitchen-bakery-vegetable waste-based, (2) bakery-dairy waste-based, or (3) homemade grain-based, while those on a large-scale farm were fed a commercial diet (Table 1). The pigs on SUFs were either stunned mechanically or non-stunned, while those from the commercial farm were electrically stunned. The farmers on SUFs either practiced throat or cervical spine sticking during slaughter and the commercial abattoir also used throat sticking.

2.5. Carcass measurements

Muscle pH and temperature were measured 45 min after slaughter using a calibrated portable pH meter with automatic temperature compensation (pH5 Tester Kit, IP 67, XS Instruments, Italy). The measurements were taken on the 12th and 13th ribs of the left *longissimus thoracis et lumborum* (LTL) muscle both on the farm and at the abattoir by the researcher. The pH meter was calibrated using two standard buffers with pH values of 4.0 and 7.0 at 25.0 ± 2.0 °C. This was followed by weighing the warm carcass using a rechargeable and foldable industrial electro-sensitive weighing scale (A12E, MICRO-LCH, B&R Scale Services, South Africa). Carcass subcutaneous fat thickness was measured using a ruler at 45 mm from the backfat midline between the 11th and 12th ribs following the Hennessy Grading Systems (Auckland, New Zealand) and classified as follows: $P = \leq 12$ mm fat, $O = 13 – 17$ mm, $R = 18 – 22$ mm, $C = 23 – 27$ mm, $U = 28 – 32$ mm and $S = > 32$ mm according to the PORCUS classification system (DAFF, 2015). Carcass

Table 1
Nutrient composition of locally available feedstuffs fed to pigs on smallholder farms in the Cape Metropole District, South Africa.

Feed	n	Dry matter (%)	Crude protein (%)	Crude fibre (%)	Ash (%)	Ether extract (%)	Gross energy (MJ/ kg)
Bakery byproducts waste		**58.3 ± 3.40**	**11.3 ± 167**	**1.57 ± 0.83**	**3.05 ± 1.00**	**11.5 ± 2.24**	**19.3 ± 0.44**
Bread[b,d]	6	59.9 ± 1.62	10.6 ± 0.35	0.39 ± 0.18	2.76 ± 0.07	0.50 ± 0.02	17.2 ± 0.04
Buns[b,d]	4	69.3 ± 2.67	14.8 ± 0.76	0.29 ± 0.21	2.48 ± 0.05	3.60 ± 1.74	18.9 ± 0.71
Flour dough[c]	8	62.6 ± 10.9	8.45 ± 2.02	3.23 ± 3.40	2.40 ± 1.09	19.2 ± 2.51	20.3 ± 1.60
Pizza dough[e]	2	54.3 ± 3.46	9.87 ± 2.64	0.92 ± 0.08	8.23 ± 2.27	19.6 ± 2.81	18.3 ± 1.47
Buns and milk[b,d]	6	36.9 ± 8.89	16.1 ± 0.15	0.21 ± 0.10	2.95 ± 0.14	7.09 ± 1.06	19.9 ± 0.13
Dairy byproducts waste		**49.1 ± 3.21**	**31.3 ± 3.66**	**4.08 ± 1.65**	**8.11 ± 0.98**	**49.0 ± 2.30**	**27.6 ± 5.21**
Ice cream and cheese[b,d]	2	49.1 ± 3.21	31.3 ± 3.66	4.08 ± 1.65	8.11 ± 0.98	49.0 ± 2.30	27.6 ± 5.21
Commercial feed		**88.2 ± 8.33**	**14.4 ± 4.09**	**4.80 ± 2.03**	**6.17 ± 2.37**	**3.59 ± 5.49**	**17.1 ± 1.08**
Grower pellets[a]	10	87.6 ± 4.22	14.4 ± 4.02	6.67 ± 7.32	6.29 ± 1.54	3.60 ± 1.58	17.4 ± 0.39
Whey pellets[a]	4	88.9 ± 5.23	14.4 ± 2.96	2.93 ± 0.92	6.05 ± 1.04	3.57 ±.0 0.96	16.9 ± 0.35
Grains		**78.4 ± 5.89**	**7.46 ± 2.89**	**0.74 ± 1.43**	**1.26 ± 1.68**	**3.78 ± 3.88**	**17.0 ± 0.76**
Malt[a]	2	89.1 ± 5.36	7.95 ± 1.10	0.65 ± 0.08	1.43 ± 0.05	2.65 ± 0.09	16.4 ± 0.30
Millet[a]	2	89.6 ± 5.41	8.49 ± 1.74	2.08 ± 0.25	1.50 ± 0.05	2.82 ± 0.10	17.0 ± 0.36
Oats[a]	2	90.9 ± 6.45	13.2 ± 2.49	0.03 ± 0.01	1.78 ± 0.08	9.14 ± 0.96	18.7 ± 0.45
Starch powder[a]	2	43.9 ± 3.85	0.19 ± 0.18	0.20 ± 0.06	0.34 ± 0.01	0.50 ± 0.53	15.7 ± 0.28
Kitchen waste		**37.6 ± 3.55**	**13.4 ± 1.74**	**2.08 ± 0.86**	**4.23 ± 1.01**	**12.2 ± 2.34**	**19.7 ± 0.46**
Kitchen waste mix (swill)[c,e]	10	33.4 ± 9.05	15.3 ± 3.45	2.75 ± 0.78	5.08 ± 1.69	16.1 ± 8.38	20.6 ± 1.51
Samp[c]	2	42.1 ± 4.22	4.92 ± 1.85	0.42 ± 0.05	1.21 ± 0.58	0.69 ± 0.45	16.7 ± 0.86
Yellow fried rice[c]	2	73.1 ± 25.9	6.98 ± 0.81	1.34 ± 0.81	2.78 ± 2.58	3.86 ± 1.41	17.2 ± 0.35
Uncooked soaked spaghetti[a]	2	48.0 ± 4.58	12.9 ± 2.38	0.07 ± 0.00	0.73 ± 0.06	0.73 ± 0.005	17.4 ± 0.10
Vegetables, fruits and forages		**9.54 ± 3.72**	**12.7 ± 1.83**	**12.8 ± 0.91**	**11.8 ± 1.06**	**2.56 ± 2.45**	**15.7 ± 0.48**
Cabbage[c]	4	9.27 ± 2.84	16.8 ± 1.61	15.6 ± 0.54	12.9 ± 2.37	2.83 ± 0.69	15.4 ± 0.21
Carrots[c,e]	2	8.16 ± 0.73	5.76 ± 0.60	9.15 ± 1.10	14.2 ± 4.10	1.86 ± 0.36	14.8 ± 0.49
Oranges[d]	4	15.2 ± 2.74	5.45 ± 1.35	7.00 ± 1.35	3.56 ± 0.82	2.04 ± 0.68	16.2 ± 0.56
Pumpkin[d]	4	4.93 ± 0.03	9.08 ± 6.06	17.4 ± 1.71	9.17 ± 1.39	2.27 ± 0.5	16.8 ± 0.94
Parsley herb[e]	4	10.1 ± 2.25	26.3 ± 5.51	15.4 ± 0.51	19.2 ± 2.35	4.22 ± 0.90	15.2 ± 0.05

a, b, c, d, e = suburbs where the feedstiffs were sourced; a = IthembaLab; b = Khayelitsha; c = Mfuleni; d = Penhill; e = Strand.

conformation of pigs sourced from the SUFs and a large-scale commercial farm were classed on a scale of 1 to 5: 1 = very flat, 2 = flat, 3 = medium, 4 = round, and 5 = very round (DAFF, 2015).

The carcasses were transported in a 2 × 1.5 × 2.2 m mobile cold room (± 4 °C; SWI-1000; Swift Air-Conditioning and Refrigeration, Pretoria, South Africa) to Stellenbosch University Meat Science laboratory and stored in a chiller room (± 4 °C). After 24 h post-mortem, cold carcass weights and muscle pH were measured, followed by removal of the left LTL muscle from each carcass for meat analyses. For the control group, six left LTL muscle samples were excised from the carcass at a commercial abattoir 24 h post-mortem for meat quality analyses. The muscle pH and temperature of the carcasses from the commercial farm were not measured because the meaty safety regulations implemented at the commercial abattoir prohibited touching and pricking of the carcasses intended for public human consumption, especially with laboratory equipment.

2.6. Measurement of meat physicochemical attributes

All visible fat from pork sourced from smallholder and commercial farms was removed from the LTL meat samples. The LTL was cut into five prisms (80 mm length × 50 mm width × 20 mm depth) during sampling, beginning at the cranial end and progressing to the caudal end. The prism length was taken parallel to the muscle fibers and width from the center of the muscle. The prisms were assigned for colour plus drip loss (2 prisms), cooking loss plus shear force (2 prisms), proximate (1 prism), and FA (1 prism) analyses. The meat samples for the proximate were homogenised using a knife mill (FOSS Knifetec™ 1095, Höganäs., Sweden), vacuum-sealed, and kept at −20 °C until further analyses. The meat samples for FA were kept intact at −80 °C pending analyses.

2.6.1. Meat colour and drip loss measurements

Pork lightness (L*), redness (a*), and yellowness (b*) coordinates were measured after 30 min of blooming. The readings were taken perpendicular to the muscle fibres and repeated three times at various locations on the prism facet using a calibrated Spectro-guide 45/0 gloss colorimeter (illuminant D65, 11 mm diameter aperture, 10° standard observer angle; BYK-209 Gardner GmbH, Gerestried, Germany). The mean of the three values for each colour coordinate was computed to obtain a representative reading. The colour guide was calibrated with black and white tiles before taking measurements. After colour measurements, meat prisms were suspended in inflated plastic bags and hung in a cold room at 4.0 ± 0.4 °C cabinet chiller for 24 h to measure drip loss. The analysis was performed in duplicate and drip loss was expressed as a percentage of weight loss after 24 h (Honikel, 1998).

2.6.2. Meat proximate analyses

To measure the moisture and ash of pork samples, AOAC (2016) procedures 950.46 and 920.153 were used, respectively. Intramuscular fat (IMF) content was measured by extracting lipids from a 5 g pork sample with a 2:1 chloroform/ methanol solution (Lee et al., 1996). The defatted pork samples from the total fat analysis were dried at 60 °C for 48 h before being ground to quantify protein (method 992.15; AOAC, 2016) on a N analyser using the Dumas combustion method (LECO® FP828, LECO Corporation, St. Joseph, MI, USA). The proximate analyses were all run in duplicate.

2.6.3. Cooking loss and shear force analyses

Muscle cooking loss was determined as a percentage loss in weight after two pork prisms were cooked in a water bath at 80 °C to an internal temperature of 75 °C (Honikel, 1998). A thermocouple placed in the prism's geometric centre was attached to a digital temperature monitor (Hanna Instruments, Bellville, South Africa) to measure their internal temperature. Six cuboids measuring 20 × 10 × 10 mm were cut off from each prism along its fibre grain for the shear force testing. The shear force was measured using an Instron 3345 (Universal) machine (Instron® Products, Norwood, MA) equipped with a 500 N load cell and a 1 mm thick V-shaped Warner Bratzler cutting blade with a speed of 200 mm/ min by slicing through each cuboid perpendicular to the muscle fibre. The shear force was calculated in Newtons as an average of all six cuboids. All samples were cooked in one batch, and the cooking loss and shear force analyses were duplicated.

2.6.4. Meat fatty acids analyses

The Folch et al. (1957) method was used to extract total lipids from freeze-dried 1 g of pork in a 2:1 chloroform/ methanol solution. For the internal standard, 10 mg of lipid aliquots were dissolved in 1 mL of toluene containing 1 mg of c10-heptadecenoic (c10–17:1) acid methyl ester (standard no. U-42 M, Nu-Chek-Prep Inc., Elysian, MN, USA). After lipid extraction, FAs were converted into FA methyl esters (FAMEs) using a two-step acid-base (0.3 mL of sodium methoxide and 1 mL of methanolic hydrochloric acid) methylation method outlined by Kramer et al. (2008). Following methylation, the samples were allowed to reach room temperature before being mixed with 1 mL of deionised water and 3 mL of hexane. The mixture was centrifuged for 5 min at 1000 g to separate the phases. The FAMEs in the hexane upper organic phase were transferred to a vial containing sodium sulphate to remove any water. The FAMEs were analysed using a 175 °C gas chromatograph temperature program equipped with a highly polar 100 m capillary column described by Uushona et al. (2021). Briefly, a gas chromatograph (Gas chromatograph, 6890N, Agilent Technologies, Santa Clara USA) coupled to a flame ionisation detector (FID, Palo Alto, CA, USA) with a polar RT-2560 (100 m, 0.25 mm ID, 0.20 µmol film thickness; Restek, USA) capillary column was used to separate the FAMEs. The flow rate of hydrogen gas used was 1 mL/ min. One µL of the sample was injected into the machine in a split ratio of 5:1 while maintaining an injector temperature of 250 °C. The FAMEs were detected using retention times comparative to a gas chromatograph 463 reference standard injected with a combination of four positional conjugated linoleic acid (CLA) isomers with standard number UC-59M. All FAMEs standards were identified from Nu-Chek-Prep Inc. (Elysian, MN, USA), and their quantities were determined using internal standard-based calculations and chromatographic peak area. The FAMEs were reported as mg/ 100 g of fresh meat.

2.7. Statistical analyses

The feed data was subjected to PROC MEANS to generate the means and standard deviations of the chemical composition of the feedstuffs. Carcass attributes, meat proximate composition and FA profile data were subjected to analysis of variance using PROC MIXED of SAS 9.4 with diet as the fixed factor and suburb as the random factor. The statistical model was: $y_{ij} = \mu + \tau_i + \varepsilon_{ij}$, where y_{ij} = was the response variable; μ = the overall mean; τ_i = diet (kitchen-bakery-vegetable waste-based, bakery-dairy waste-based, homemade grain-based and commercial diet), and ε_{ij} = random error. In the statistical model for the analyses of meat physical data, diet was matched with sticking method to avoid confounding effects, and stunning was used as a covariate. The model for the analyses of the effects of stunning on meat physical attributes excluded data from the pigs slaughtered at commercial abattoir due to the confounding effect of the stunning method with the diet. Table 3 illustrates the layout treatments and sample size used for the current study. Differences between the means of treatments or stunning methods were separated at $P \leq 0.05$ using Tukey's test. A chi-square test (PROC FREQ of SAS 9.4) was performed to evaluate associations between pig carcass classes and farm type.

3. Results

3.1. Chemical composition of pig feedstuffs on SUFs

The selected farms intensively raised pigs using various types of feeds. Farmers in Mfuleni and Strand suburbs mostly fed the kitchen-bakery-vegetable waste-based diet, whereas those in Khayelitsha and Penhill suburbs fed a bakery-dairy waste-based diet (Table 1). The IthembaLab suburb farm fed a homemade grain-based diet, while the large-scale farm fed a complete commercial diet (Table 1). Grains and commercial feeds predominating the homemade grain-based diet had the highest DM contents, while vegetables, fruits, and forages mostly found in the kitchen-bakery-vegetable waste-based diet had the lowest DM (Table 1). Dairy waste primarily found in the bakery-dairy waste-based contained more protein, ether extract, and gross energy than the other feedstuffs (Table 1). Regarding CF (Table 1) and α-linolenic acid (Table 2), vegetables, fruits, and forages stood out among other feedstuffs. Dairy waste in the bakery-dairy waste-based diet had relatively less polyunsaturated FA (PUFA) than the other feedstuffs (Table 2). The FA profiles for the rest of the feedstuffs were comparable with linoleic, stearic, and palmitic acids, in that order being the major FA (Table 2).

3.2. Slaughter practices on SUFs

3.2.1. Preslaughter handling practices

Smallholder farmers in all five suburbs employed casual workers to slaughter the pigs. In addition, farmers in Strand, Mfuleni, and Khayelitsha suburbs used a community slaughterman and family members. Except for the IthembaLab farm that used a measuring tape to weigh the pigs, the rest of the surveyed SUFs conducted visual appraisals to determine the slaughter weight. All the SUFs had no pig handling equipment and facilities. In IthembaLab, pigs were caught using a bait, tied to a pole and distracted with feed before being stunned. For the remaining SUFs, preslaughter handling generally involved in-pen chasing, grabbing and lifting the front and hind legs sideways and upwards to make the pig lie down on one side before slaughter.

3.2.2. Slaughter procedures

Only farmers in Ithembalab stunned pigs using a gun (Blitz™ Captive Bolt Stun, UK). The gunshot was made slightly above the eye level on the midline of the forehead. IthembaLab, Khayelitsha, and Penhill farmers used sharp knives to stick the pig's throat (Fig. 1A) and sever the carotid artery and jugular vein before bleeding for 30–60 s. Farmers from Strand and Mfuleni sticked the first cervical vertebra (Fig. 1B), severing the vertebral artery and deep cervical vein leaving the pigs to bleed for 30–60 s. At the local commercial abattoir in Cape Town, pigs were electrically stunned (240 V; 1.3 Amps; 3 s) by applying electrodes to the head, below the ears, followed by throat sticking within 30 s. After sticking, pigs were hung by their hind legs for exsanguination for 30–45 s.

3.2.3. Carcass dressing, washing and hanging procedures

The carcass dressing, washing, and hanging procedures in the five surveyed low-income, high-density suburbs had minor differences. For scalding in Strand and Penhill farms, carcasses were dipped into a boiling water-filled tank for 1-2 min, followed by manual dehairing. This was repeated twice for complete dehairing. In Mfuleni, Khayelitsha, and IthembaLab, boiling water was poured onto the carcass for 10–15 s repeatedly until dehairing was completed. Besides knives and razor blades, farmers in Strand, Penhill, Mfuleni, and Khayelitsha used tablespoons, shaving blades, corned beef tin lids, sharp stones and/ or brick breakages to remove the hairs from the pig skin. At the commercial abattoir, carcasses were submerged in a scalding tank with hot water (60.0 ± 2.0 °C) for 5 min and then passed through a dehairing machine for 1 min. The carcases were subsequently subjected to singeing by open-flame gas burners for 15 s to burn-off remaining hair.

To facilitate evisceration, the carcasses were placed on a flat surface on all the SUFs while the commercial abattoir hanged them by the hind legs on a metallic rail. In all the SUFs and the abattoir, sharp knives were used to cut open the midline of the ventral side of the pig from the rectum to the breastbone to allow the removal of all the abdominal contents. Smallholder urban farmers continuously cleaned the carcass with water while eviscerating. The slaughtering time varied across the SUFs. Khayelitsha farm was the fastest (30 min) followed by Mfuleni (35 min). The rest of the SUFs and the commercial abattoir took 45–60 min to complete slaughter. All the SUFs-dressed carcasses were placed on a flat surface pending transportation.

Table 2
Fatty acid (FA) composition (g/100 g of total FA) of locally available feedstuffs fed to pigs on smallholder urban farms in the Cape Metropole District, South Africa.

Feed		Saturated FA			Monounsaturated FA	Polyunsaturated FA		
	n	14	16	18	c9–18:1	18:2*n*-6	18:3*n*-3	22:6*n*-3
Bakery byproducts		**2.72 ± 0.32**	**31.6 ± 1.11**	**6.01 ± 0.51**	**15.0 ± 0.88**	**38.8 ± 1.77**	**2.56 ± 1.09**	**0.53 ± 0.05**
Bread[b,d]	6	1.29 ± 0.48	25.7 ± 3.12	4.43 ± 0.76	12.4 ± 2.93	50.6 ± 5.92	3.06 ± 0.61	0.65 ± 0.33
Buns[b,d]	4	1.06 ± 0.14	27.9 ± 2.87	6.67 ± 1.35	15.1 ± 1.40	44.3 ± 2.74	2.97 ± 0.45	0.54 ± 0.03
Flour dough[c]	8	1.79 ± 0.27	34.1 ± 1.78	8.09 ± 7.42	14.4 ± 4.36	35.9 ± 2.93	1.93 ± 0.17	0.57 ± 0.20
Pizza dough[e]	2	5.58 ± 0.01	36.8 ± 0.15	3.31 ± 0.07	21.6 ± 0.51	25.9 ± 0.50	2.64 ± 0.01	0.27 ± 0.03
Buns and milk[b,d]	6	5.54 ± 2.59	35.2 ± 1.07	5.29 ± 0.23	16.1 ± 1.86	31.7 ± 5.77	2.61 ± 0.18	0.43 ± 0.06
Dairy byproducts		**20.1 ± 1.12**	**40.3 ± 4.04**	**7.39 ± 1.83**	**20.7 ± 3.18**	**2.63 ± 6.39**	**0.68 ± 3.92**	**0.06 ± 0.18**
Ice cream and cheese[b,d]	2	20.1 ± 1.12	40.3 ± 4.04	7.39 ± 1.83	20.7 ± 3.18	2.63 ± 6.39	0.68 ± 3.92	0.06 ± 0.18
Commercial feed		**0.91 ± 0.43**	**28.2 ± 1.53**	**3.23 ± 0.69**	**21.3 ± 1.20**	**40.6 ± 2.42**	**4.00 ± 1.48**	**0.44 ± 0.07**
Grower pellets[a]	10	0.85 ± 0.25	30.6 ± 6.67	3.32 ± 1.05	23.3 ± 5.33	36.7 ± 12.4	3.65 ± 1.47	0.38 ± 0.07
Whey pellets[a]	4	1.07 ± 0.10	22.2 ± 0.57	3.03 ± 0.18	16.1 ± 1.94	50.2 ± 1.37	4.89 ± 0.25	0.62 ± 0.02
Grains		**1.74 ± 0.46**	**29.4 ± 2.01**	**1.82 ± 0.91**	**22.4 ± 1.59**	**41.6 ± 3.20**	**2.29 ± 1.96**	**0.34 ± 0.09**
Malt[a]	2	0.27 ± 0.00	24.5 ± 0.74	1.46 ± 0.00	27.9 ± 0.28	42.9 ± 0.49	2.30 ± 0.02	0.11 ± 0.00
Millet[a]	2	0.36 ± 0.00	24.0 ± 0.09	1.66 ± 0.01	28.3 ± 0.08	42.4 ± 0.10	2.39 ± 0.06	0.14 ± 0.00
Oats[a]	2	1.14 ± 0.04	36.4 ± 0.20	1.56 ± 0.04	19.4 ± 0.04	38.5 ± 0.01	1.54 ± 0.03	0.21 ± 0.03
Starch powder[a]	2	1.81 ± 0.04	32.5 ± 0.02	2.59 ± 0.02	14.1 ± 0.33	41.3 ± 0.53	2.95 ± 0.10	0.91 ± 0.07
Kitchen waste		**2.51 ± 0.40**	**30.3 ± 1.43**	**4.22 ± 0.65**	**19.1 ± 1.12**	**36.4 ± 2.26**	**4.10 ± 1.39**	**0.65 ± 0.06**
Kitchen waste mix (swill)[c,e]	10	2.43 ± 0.27	27.6 ± 1.55	5.12 ± 0.69	21.1 ± 2.74	35.3 ± 3.38	5.22 ± 1.43	0.73 ± 0.08
Samp[c]	2	1.69 ± 0.08	36.1 ± 0.26	3.48 ± 0.12	16.6 ± 0.01	35.2 ± 0.09	1.84 ± 0.08	0.67 ± 0.10
Yellow fried rice[c]	2	5.19 ± 0.08	37.6 ± 0.94	3.44 ± 0.20	20.5 ± 0.75	27.5 ± 0.24	2.23 ± 0.22	0.57 ± 0.12
Uncooked soaked spaghetti[a]	2	1.00 ± 0.14	30.2 ± 0.95	1.31 ± 0.05	10.5 ± 0.07	52.2 ± 1.37	2.61 ± 0.09	0.36 ± 0.01
Vegetables, fruits and forage		**2.17 ± 0.37**	**32.0 ± 1.35**	**2.62 ± 0.61**	**10.9 ± 1.06**	**25.3 ± 2.13**	**22.2 ± 1.31**	**0.57 ± 0.06**
Cabbage[c]	4	0.95 ± 0.52	24.6 ± 5.49	1.79 ± 0.68	12.7 ± 3.95	16.8 ± 0.76	40.3 ± 4.29	0.46 ± 0.10
Carrots[c,e]	2	1.07 ± 0.07	34.9 ± 0.47	2.44 ± 0.04	5.54 ± 0.01	47.4 ± 0.24	6.54 ± 0.41	0.38 ± 0.04
Oranges[d]	4	2.98 ± 0.42	30.3 ± 0.32	2.85 ± 0.23	9.61 ± 0.32	30.1 ± 1.64	13.4 ± 0.51	1.14 ± 0.19
Pumpkin[d]	4	1.70 ± 0.34	42.2 ± 6.18	3.48 ± 1.16	9.52 ± 4.98	18.3 ± 2.50	21.8 ± 1.55	0.55 ± 0.27
Parsley herb[e]	4	3.59 ± 2.60	29.6 ± 0.67	2.46 ± 0.92	14.6 ± 0.04	25.0 ± 1.27	20.9 ± 6.73	0.22 ± 0.02

a, b, c, d, e = suburbs where the feedstuffs were sourced; *a* = IthembaLab; *b* = Khayelitsha; *c* = Mfuleni; *d* = Penhill; *e* = Strand.

Table 3
Treatment layout and sample size (n) used to assess carcass attributes, pork quality and fatty acid profiles of smallholder pigs in the Cape Metropole District, South Africa.

Smallholder urban farm (suburb name)	n	Diet and sticking method treatments	n	Stunning Method	n
IthembaLab	6	[1]Homemade, throat sticking	6	Mechanical	6
Khayelitsha	6	[2]Bakery-dairy, throat sticking	12	Non-stunned	24
Penhill	6	Bakery-dairy, throat sticking		Non-stunned	
Mfuleni	6	[3]Kitchen-bakery-vegetable, cervical spine sticking	12	Non-stunned	
Strand	6	Kitchen-bakery-vegetable, cervical spine sticking		Non-stunned	
Commercial farm	6	[4]Commercial feed, throat sticking	6	Electrical	6

[1]Homemade = home formulated grain-based diet from IthembaLab; [2]Bakery = [2]Bakery-dairy waste-based diet from Khayelitsha and Penhill; [3]Kitchen = kitchen-bakery-vegetable waste-based diet from Mfuleni and Strand; [4]Commercial-throat = complete commercially manufactured diet from largescale farm.

3.3. Carcass attributes, pork quality and fatty acid profiles of pigs raised and slaughtered on smallholder urban farms

Carcasses from pigs fed different diets on SUFs fell into P, O, and R yield classes, while those from pigs fed the commercial diet were exclusively in the P and O classes ($\chi^2 = 20.39$; $\varphi_c = 0.53$; $P \leq 0.05$). About 95 % of the pig carcasses had a medium conformation (class 3) regardless of the diet ($P > 0.05$). Smallholder pigs fed the homemade grain-based diet had the heaviest slaughter and carcass weights followed by kitchen-bakery-vegetable waste-based and bakery-dairy waste-based diets, respectively ($P \leq 0.05$; Table 4). Loin muscle from pigs fed the homemade grain-based diet had the highest subcutaneous fat and IMF contents, the kitchen-bakery-vegetable and bakery-dairy waste-based diets had intermediate values, and the commercial diet had the lowest values ($P \leq 0.05$; Table 4). Bakery-dairy waste-based diets produced meat with the highest moisture content while homemade grain-based diet had the lowest values ($P \leq 0.05$; Table 4). Meat CP contents were in the order of commercial diet > kitchen-bakery-vegetable waste-based > homemade grain-based > bakery-dairy waste-based diets ($P \leq 0.05$; Table 4). Homemade grain-based and bakery-dairy waste-based diets had higher ($P \leq 0.05$) ash contents than the other diets (Table 4).

Pork loin pH_{45} values were in the treatment order of homemade waste-based diet, throat sticking > bakery-dairy waste-based diet, throat sticking > kitchen-bakery-vegetable waste-based diet, cervical spine sticking ($P \leq 0.05$; Table 5). The pH_{24} values for pork were higher ($P \leq 0.05$) for the SUF-based treatments than the commercial diet, throat sticking treatment (Table 5). Loin muscle temperature at 45 min was highest in carcasses from pigs fed the bakery-dairy waste-based and slaughtered by throat sticking, while those fed the kitchen-bakery-vegetable waste-based diet and slaughtered by cervical spine sticking had intermediate values and pigs fed the homemade grain-based diet and slaughtered by throat sticking had the least values ($P \leq 0.05$; Table 5). Pigs on the commercial diet, throat sticking treatment had higher ($P \leq 0.05$) muscle temperature values at 24 h than those on the bakery-dairy waste-based diet, throat sticking and kitchen-bakery-vegetable waste-based diet, cervical spine sticking treatments but was not different ($P > 0.05$) from those on the homemade waste-based diet, throat sticking treatment (Table 5).

The commercial diet, throat sticking treatment produced meat with lower ($P \leq 0.05$) L*, a*, b*, H° and C° values and higher ($P \leq 0.05$) shear force values than the SUF-based treatments (Table 5). Pork on the kitchen-bakery-vegetable waste-based diet, cervical spine sticking treatment had higher ($P \leq 0.05$) drip loss values than that on the other SUF-based treatments but was not different ($P > 0.05$) from that on the commercial diet, throat sticking treatment (Table 5). Relative to other treatments, cooking loss values were higher ($P \leq 0.05$) for pork fed the homemade grain-based and bakery-dairy wasted-based diets and slaughtered using the throat sticking method (Table 5). Regarding

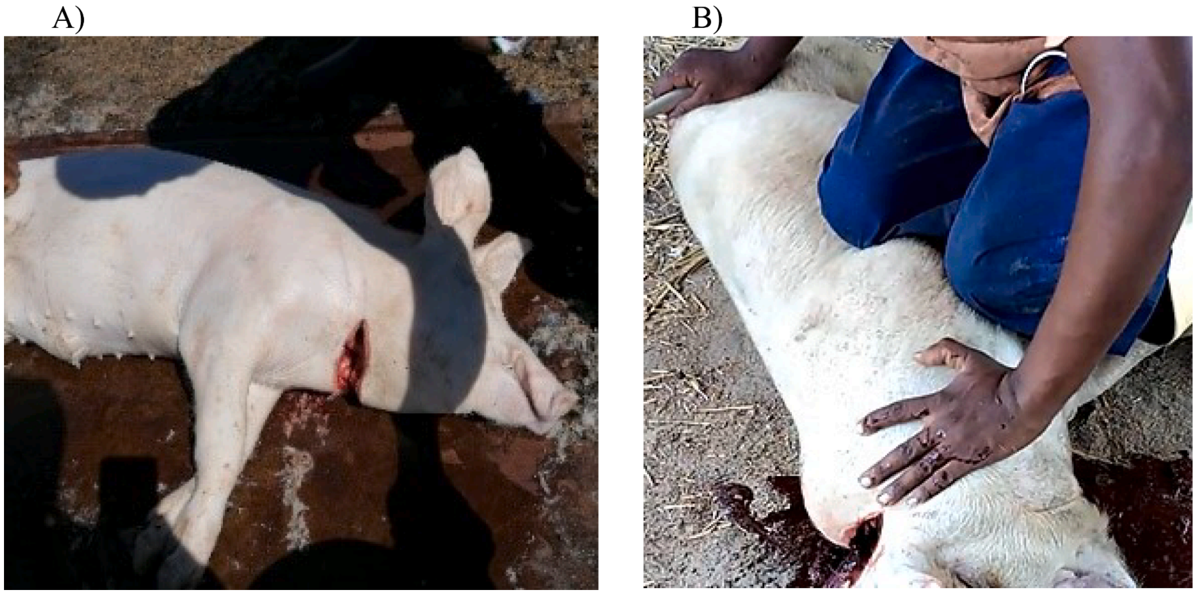

Fig. 1. Throat (A) and cervical vertebrae (B) sticking methods used on smallholder urban farms in the Cape Metropole District, South Africa.

Table 4
Diet effects on carcass attributes and proximate composition of pork from pigs raised and slaughtered on smallholder farms in the Cape Metropole District, South Africa.

Variables	Diet				*P* value
	Homemade[1]	Bakery[2]	Kitchen[3]	Commercial[4]	
Slaughter weight (kg)	68.2 ± 3.04[a]	43.8 ± 2.24[c]	45.9 ± 1.91[b]	–	0.001
Warm carcass weight (kg)	56.8 ± 1.39[a]	32.0 ± 1.84[c]	37.5 ± 1.30[b]	–	0.001
Cold carcass weight (kg)	55.6 ± 1.24[a]	31.3 ± 1.82[c]	36.5 ± 1.23[b]	–	0.001
Subcutaneous fat (mm)	19.0 ± 1.14[a]	15.9 ± 0.80[b]	17.1 ± 0.80[ab]	12.0 ± 1.10[c]	0.001
Muscle moisture (%)	71.9 ± 0.36[c]	75.9 ± 0.37[a]	74.5 ± 0.26[ab]	73.8 ± 0.34[b]	0.001
Muscle crude protein (%)	20.5 ± 0.32[c]	19.2 ± 0.23[d]	21.6 ± 0.23[b]	23.4 ± 0.30[a]	0.001
Muscle intramuscular fat (%)	3.68 ± 0.17[a]	3.07 ± 0.12[b]	3.08 ± 0.12[b]	2.15 ± 0.17[c]	0.001
Muscle ash (%)	3.84 ± 0.31[a]	3.19 ± 0.22[a]	2.17 ± 0.22[b]	1.33 ± 0.28[c]	0.001

[a, b, c] = means in the same row not sharing a common superscript are significantly different ($P \leq 0.05$); *N* = Newtons; [1, 2, 3] = feedstuffs categorised in diets according to type and source (suburbs); [1]Homemade = home formulated grain-based diet from IthembaLab; [2]Bakery = [2]Bakery-dairy waste-based diet from Khayelitsha and Penhill; [3]Kitchen = kitchen-bakery-vegetable waste-based diet from Mfuleni and Strand; [4]Commercial-throat = complete commercially manufactured diet from largescale farm.

Table 5
Diet and sticking method-based treatments effects on physical quality of pork from pigs raised and slaughtered on smallholder farms in the Cape Metropole District, South Africa.

Variables	Diet and sticking method-based treatments				*P* value
	Homemade-Throat[1]	Bakery-Throat[2]	Kitchen-Cervical spine[3]	Commercial-Throat[4]	
Muscle pH (45 min)	6.84 ± 0.05[a]	6.78 ± 0.05[b]	6.51 ± 0.04[c]	–	0.001
Muscle pH (24 h)	5.70 ± 0.04[a]	5.65 ± 0.03[a]	5.62 ± 0.03[a]	5.52 ± 0.04[b]	0.018
Muscle temperature (45 min)	33.0 ± 0.28[c]	36.0 ± 0.40[a]	34.0 ± 0.28[b]	–	0.001
Muscle temperature (24 h)	9.64 ± 0.30[ab]	8.41 ± 0.21[c]	8.80 ± 0.21[bc]	9.91 ± 0.28[a]	0.001
Muscle lightness (L*)	58.4 ± 0.66[b]	59.9 ± 0.47[b]	63.6 ± 0.47[a]	55.8 ± 0.48[c]	0.001
Muscle redness (a*)	5.44 ± 0.30[ab]	6.31 ± 0.21[a]	5.17 ± 0.21[b]	3.52 ± 0.29[c]	0.001
Muscle yellowness (b*)	11.5 ± 0.28[a]	11.0 ± 0.20[a]	11.4 ± 0.20[a]	10.0 ± 0.29[b]	0.001
Muscle hue angle (H°)	60.4 ± 0.69[b]	70.8 ± 0.98[a]	64.8 ± 0.98[b]	66.0 ± 0.69[c]	0.001
Chroma (C°)	12.8 ± 0.25[a]	10.6 ± 0.35[a]	12.8 ± 0.35[a]	12.6 ± 0.26[b]	0.001
Muscle drip loss (%)	6.22 ± 0.76[b]	5.79 ± 0.54[b]	8.78 ± 0.54[a]	6.52 ± 0.75[ab]	0.001
Muscle cooking loss (%)	38.9 ± 0.86[a]	41.2 ± 0.62[a]	36.1 ± 0.61[b]	35.1 ± 0.83[b]	0.001
Muscle shear force (N)	34.1 ± 1.03[b]	31.6 ± 0.73[b]	30.8 ± 0.73[b]	44.9 ± 1.15[a]	0.001

[a, b, c] = means in the same row not sharing a common superscript are significantly different ($P \leq 0.05$); *N* = Newtons; [1, 2, 3] = feedstuffs categorised in diets according to type and source (suburbs); [1]Homemade-Throat = home formulated grain-based diet and throat sticking from IthembaLab; [2]Bakery-Throat = [2]Bakery-dairy waste-based diet and throat sticking from Khayelitsha and Penhill; [3]Kitchen = kitchen-bakery-vegetable waste-based diet and cervical sticking from Mfuleni and Strand; [4]Commercial-throat = complete commercially manufactured diet and throat sticking from largescale farm.

Table 6
Effects of stunning method on pork physical attributes of the pigs raised and slaughtered on smallholder farms in the Cape Metropole District, South Africa.

Variables	No stunning[1] (n = 24)	Mechanical[2] (n = 6)	P value
Muscle temperature (45 min)	35.4 ± 0.21	33.0 ± 0.41	0.001
Muscle pH (45 min)	6.60 ± 0.03	6.84 ± 0.05	0.001
Muscle pH (24 h)	5.62 ± 0.06	5.71 ± 0.07	0.042
Muscle lightness (L*)	61.2 ± 1.19	59.4 ± 1.40	0.080
Muscle redness (a*)	6.28 ± 1.10	4.36 ± 1.13	0.001
Muscle yellowness (b*)	11.5 ± 0.52	11.1 ± 059	0.298
Muscle drip loss (%)	7.29 ± 1.50	7.62 ± 1.68	0.719
Muscle cooking loss (%)	38.6 ± 2.53	36.5 ± 2.67	0.039
Muscle shear force (N)	31.2 ± 0.51	34.1 ± 1.05	0.014

[a, b] = Least square means in the same row not sharing a common superscript are significantly different ($P \leq 0.05$); N = Newtons; [1]No stunning = Khayelitsha, Mfuleni, Penhill and Strand suburbs did not stun pigs before slaughter; [2]Mechanical = IthembaLab suburb used a gun to stun pigs before slaughter.

effects of stunning, gun stunning produced carcasses with higher ($P \leq 0.05$) pH_{45}, pH_{24}, and shear force than non-stunning (Table 6). Muscle temperature at 45 min, redness and cooking loss were higher ($P \leq 0.05$) for the non-stunned carcasses than the gun-stunned ones (Table 6).

Total FA content was higher ($P \leq 0.05$) for the homemade grain-based and bakery-dairy waste-based diets than the other diets (Table 7). For total PUFA, individual and total n-6 PUFA, pork from pigs fed the homemade grain-based diet had higher ($P \leq 0.05$) contents than that from animals fed the other diets except for 18:3n-6 and 20:4n-6 contents, which were similar ($P > 0.05$) to the bakery-dairy waste-based diet (Table 7). Contents of total n-3 PUFA and 18:3n-3 in pork were in the order of kitchen-bakery-vegetable waste-based > bakery-dairy waste-based = homemade grain-based > commercial diet (Table 7). Relative to the other diets, the contents of 20:5n-3 were higher ($P \leq 0.05$) in pork from the homemade grain-based and bakery-dairy waste-based diets, while 22:6n-3 was lower ($P \leq 0.05$) in the commercial diet (Table 7). The homemade grain-based and bakery-dairy waste-based diets had higher ($P \leq 0.05$) contents of rumenic acid (RA, c9,t11–18:2) than the kitchen-bakery-vegetable waste-based diets (Table 7). The contents of c12,t10–18:2 were lower ($P \leq 0.05$) in the homemade grain-based diet than in the other diets (Table 7). For the total and majority of individual monounsaturated FA (MUFA) and saturated FA (SFA), the homemade grain-based and bakery-dairy waste-based diets had higher ($P \leq 0.05$) contents than the other diets. The contents of c10–15:1, 12:0, 15:0, 17:0, and 22:0 were an exception, with the commercial diet having lower ($P \leq 0.05$) values than the other diets (Table 7).

4. Discussion

The higher DM content of grains and commercial feed in the

Table 7
Effects of diet on fatty acid profile of fresh pork (mg/100 g of muscle) from pigs raised and slaughtered on smallholder farms in the Cape Metropole District, South Africa.

	Diet				
Variables	Homemade[1]	Bakery[2]	Kitchen[3]	Commercial[4]	P-value
Σ Fatty acids	3067 ± 257.3[a]	2348 ± 181.9[a]	1441 ± 181.9[b]	1062.2 ± 238.4[b]	0.001
Polyunsaturated fatty acids (PUFA)					
Σ PUFA	404 ± 29.8[a]	293 ± 21.0[b]	303 ± 21.0[b]	237.7 ± 27.4[b]	0.001
Σ n-6 PUFA	372 ± 25.4[a]	257 ± 17.9[b]	263 ± 17.9[b]	219.2 ± 23.3[b]	0.001
18:2n-6	299 ± 21.0[a]	186 ± 14.8[b]	209 ± 14.8[b]	167.2 ± 19.3[b]	0.001
18:3n-6	6.38 ± 0.54[a]	5.07 ± 0.38[a]	3.08 ± 0.38[b]	2.56 ± 0.50[b]	0.001
20:2n-6	12.6 ± 1.50[a]	7.26 ± 1.06[b]	5.87 ± 1.06[b]	3.17 ± 1.38[b]	0.001
20:4n-6	41.4 ± 3.56[a]	50.3 ± 2.51[a]	36.9 ± 2.51[b]	39.2 ± 3.31[b]	0.002
22:4n-6	12.5 ± 0.87[a]	8.54 ± 0.62[b]	7.56 ± 0.62[b]	7.13 ± 0.81[b]	0.001
Σ n-3 PUFA	21.5 ± 4.74[b]	26.4 ± 3.35[b]	33.5 ± 3.35[a]	12.5 ± 4.36[c]	0.004
18:3n-3	12.5 ± 3.72[b]	14.5 ± 2.63[b]	22.0 ± 2.63[a]	4.19 ± 3.42[c]	0.002
20:3n-3	0.97 ± 0.21	0.66 ± 0.15	0.76 ± 0.15	0.27 ± 0.20	0.092
20:5n-3	0.79 ± 0.11[a]	0.75 ± 0.08[a]	0.42 ± 0.08[b]	0.36 ± 0.10[b]	0.001
22:5n-3	5.18 ± 0.70	6.01 ± 0.49	6.24 ± 0.49	4.78 ± 0.65	0.235
22:6n-3	4.09 ± 0.56[a]	4.48 ± 0.39[a]	4.07 ± 0.39[a]	2.89 ± 0.51[b]	0.002
Σ CLA	11.3 ± 1.45	8.77 ± 1.03	6.48 ± 1.03	5.95 ± 1.72	0.084
c9,t11–18:2	6.88 ± 0.90[a]	4.79 ± 0.64[a]	2.96 ± 0.64[b]	3.64 ± 1.10[ab]	0.042
c11,t13–18:2	3.86 ± 0.61	3.47 ± 0.43	3.07 ± 0.43	2.13 ± 0.68	0.301
c12,t10–18:2	0.65 ± 0.08[a]	0.51 ± 0.06[a]	0.45 ± 0.06[a]	0.18 ± 0.07[b]	0.001
Monounsaturated fatty acids (MUFA)					
Σ MUFA	1367 ± 118.9[a]	1023 ± 84.7[a]	592 ± 76.7[b]	432.3 ± 110.6[b]	0.001
c9–14:1	0.66 ± 0.13[ab]	0.85 ± 0.09[a]	0.51 ± 0.09[b]	0.26 ± 0.12[b]	0.003
c10–15:1	0.94 ± 0.13[a]	0.83 ± 0.09[a]	0.81 ± 0.09[a]	0.33 ± 0.12[b]	0.004
c9–16:1	106 ± 11.17[a]	70.7 ± 7.70[a]	26.1 ± 7.70[b]	54.3 ± 14.0[b]	0.001
c9–18:1	1072 ± 95.1[a]	811 ± 67.3[a]	499 ± 67.3[b]	316.2 ± 88.0[b]	0.001
c11–18:1	153.1 ± 13.6[a]	112 ± 9.63[a]	53.5 ± 9.63[b]	45.4 ± 12.6[b]	0.001
c11–20:1	34.2 ± 4.07[a]	28.1 ± 2.87[a]	12.0 ± 2.87[b]	15.8 ± 5.00[ab]	0.002
Saturated fatty acids (SFA)					
Σ SFA	1296 ± 126.5[a]	1035 ± 96.8[a]	547 ± 63.1[b]	392.3 ± 117.0[b]	0.001
12:0	5.26 ± 0.59[a]	4.48 ± 0.42[a]	3.79 ± 0.42[a]	1.07 ± 0.54[b]	0.001
14:0	42.7 ± 4.83[a]	36.8 ± 3.41[a]	20.3 ± 3.41[b]	10.1 ± 4.46[b]	0.001
15:0	1.76 ± 0.27[a]	1.59 ± 0.18[a]	1.69 ± 0.19[a]	0.43 ± 0.25[b]	0.001
16:0	902.2 ± 99.4[a]	705 ± 70.3[a]	349 ± 70.3[b]	257.3 ± 91.7[b]	0.001
17:0	6.55 ± 0.78[a]	6.18 ± 0.55[a]	5.42 ± 0.55[a]	2.93 ± 0.71[b]	0.003
18:0	327 ± 28.0[a]	267 ± 19.8[a]	158 ± 19.8[b]	115.0 ± 26.0[b]	0.001
20:0	8.46 ± 1.12[a]	7.76 ± 0.79[a]	3.79 ± 0.79[b]	3.62 ± 1.03[b]	0.001
22:0	0.30 ± 0.05[a]	0.43 ± 0.04[a]	0.42 ± 0.04[a]	0.23 ± 0.05[b]	0.007
24:0	2.27 ± 0.32	2.53 ± 0.23	2.25 ± 0.23	1.57 ± 0.30	0.321

[a, b] = Least square means in the same row not sharing a common superscript are significantly different ($P \leq 0.05$); ∑ = Summation (Total); [1]Homemade = home formulated grain-based diet fed IthembaLab; [2]Bakery = Bakery-dairy waste-based diet fed Khayelitsha and Penhill; [3]Kitchen = kitchen-bakery-vegetable waste-based-cervical spine treatment in Mfuleni and Strand; [4]Commercial = complete commercially manufactured diet fed feed from largescale farm.

homemade grain-based diet than other feed resources might be attributed to the postharvest processes, such as drying and moisture-proof packaging commonly used to reduce moisture content and improve shelf-life of feeds (Kumar & Kalita, 2017; Parvej et al., 2020). In contrast, the lower DM content of vegetables and fruits indicates higher moisture content and vulnerability to deterioration. These conditions call for low-tech moisture reduction interventions within SUF communities to enhance feed shelf-life for long-term storage and utilisation. Dairy byproducts that were part of the bakery-dairy waste-based diet had higher CP, EE and gross energy contents, which could be associated with the inclusion of cheese (CP, 25 %; fat, 60 %) and ice cream (CP, 3.8 %; fat, 10 %; (Mukhiddinov et al., 2021; Patel et al., 2006) . With the exception of dairy byproducts, commercial feed and kitchen swill, the CP contents of the remaining feeds were below the recommended CP requirements range (CP, 15–20 %) for growing pigs (NRC, 2012).

Feeding vegetables, fruits, and herbs like carrots, pumpkins, and parsley exclusively to pigs should be approached with caution. Despite having high alpha-linolenic acid (ALA) content, their dietary CP content is significantly lower than recommended levels (NRC, 2012). In addition, their CF content exceeds the National Research Council (NRC, 2012) recommended level (<10 %). The higher CF in these feed resources could reduce fat and protein digestion by limiting dietary energy density and increasing rumen fill, reducing animal performance (Cornescu et al., 2021; Martínez-Aispuro et al., 2023). Caution must be taken when feeding dairy byproducts as the fat content above 12 % could adversely affect feed palatability due to rancid flavour and odour (Liu et al., 2018; Wealleans et al., 2021). In addition, the high content of unsaturated FA in these products could impair ileal digestibility, resulting in reduced feed intake, growth performance and meat quality (Liu et al., 2018; Wealleans et al., 2021). Although there are no guidelines on gross energy requirements for pigs, all feedstuffs contained more than 15 MJ/kg DM, which could translate into the minimum digestible requirements of 15 MJ/kg DM for growing pigs (NRC, 2012).

As expected, linoleic acid was the main FA in most feeds as it is the dominant FA in feed of plant origin (Whetsell and Rayburn, 2022). The low PUFA content of dairy byproducts might be a result of rumen biohydrogenation process that converts up to 90 % of dietary PUFA to SFA, which are subsequently absorbed and deposited in milk (Dewanckele et al., 2020; Lindmark Månsson, 2008). The reliance of SUFs on visual appraisal to determine slaughter weight before sales was anticipated as they lack resources to buy weighing equipment and materials for the construction of pig handling facilities (Molotsi et al., 2021; Ting et al., 2023). The absence of pig handling and slaughter facilities on SUFs explains the involvement large labour force, including family members, farm workers, and/ or community slaughtermen in the slaughter process (Huyen et al., 2015; Ting et al., 2023). Most farmers used throat sticking without properly restraining the animals, which is considered unsafe as it could lead to injuries to the slaughterman and stress to the animal (Anil et al., 2000; Ting et al., 2023). The carcass dressing, washing, and hanging practices observed on SUFs are similar to those reported among informal slaughterhouses in sub-Saharan Africa (Mathobela et al., 2024) and Asian countries (Ting et al., 2023). The differences in time taken to complete the slaughter process were largely influenced by the type of slaughter equipment used as well as the number and experience of workers involved.

The classification of most carcasses from SUFs into R-class, with high subcutaneous and intramuscular fat content, was anticipated due to *ad-libitum* feeding of pigs with high-energy feedstuffs to achieve high pork fat contents preferred by the local informal urban market (Hong et al., 2016; Magqupu et al., 2024a). The R-class carcasses are considered less desirable by the elite South African consumers, as they originate from older pigs with high subcutaneous fat content (Needham et al., 2020; Van Heerden & Smith, 2013). However, a recent survey of pork sold in the Cape Metropole District's informal market revealed that consumers in such markets prefer pork from R, C, U, and S carcass classes as they consider them tastier due to their high fat contents (Magqupu et al., 2024a).

The superior slaughter and carcass weights of pigs fed the homemade grain-based diet might be attributed to the use of a complete and balanced commercial feeds that met protein and energy requirements for optimal growth (NRC, 2012; Pomar et al., 2021). The slaughter weights of pigs from SUFs were below the 100–110 kg recommended for the Landrace breed at 6–8 months of age. However, these light slaughter weights are targeted by farmers in Cape Metropole to produce lighter carcass weights (40–60 kg) preferred by the informal urban meat sector for easy handling during cleaning, processing, storage and marketing, (Molotsi et al., 2021). The higher IMF content of meat from pigs fed the homemade grain-based diet than those on the other treatments could be attributed to heavier carcass weights of animals on the former treatment (Parunović et al., 2012). The high energy contents of the other SUFs diets may have lowered their protein-to-energy ratio (0.84 vs 0.68) thereby reducing muscle protein and moisture content (Liu et al., 2015). A strong negative correlation exists between meat protein and moisture contents with fat content (Keeton et al., 2014; Olagbegi et al., 2023). The high meat yellowness and ash values from pigs raised on SUFs are reflective of high dietary minerals and bioactive phytocompounds, such as carotenoids, which are predominantly found in forages, vegetables and fruits (Heyer et al., 2006; Turyk et al., 2014; Zybert, 2023).

The disparities in carcass temperature at 45 min for the pigs raised and slaughtered on SUFs could be attributed to differences in slaughter weights, fat thickness, pig scalding temperatures and submersion time used by farmers (Daniels et al., 2022; Wicks et al., 2023). A combination of large carcasses with thick fat cover, high scalding temperatures (>65.0 °C), and extended submission times may increase carcass temperature at 45 min, potentially resulting in partially cooked carcasses that require more time to cool (Daniels et al., 2022; Wicks et al., 2023). The higher carcass temperature at 24 h observed in pigs fed the commercial diet and slaughter using the throat sticking method compared to those on the bakery-dairy waste-based diet, throat sticking treatment could be ascribed to their higher warm carcass weights (90 ± 10 kg), which may have reduced the surface area-to-volume ratio, thereby limiting heat loss (Čobanović et al., 2016; Djimsa et al., 2022).

The low pH_{45} values of carcasses on the kitchen-bakery-vegetable waste-based diet, cervical spine sticking treatment compared to those on the other treatments could be largely attributable to the sticking method used that predisposes pigs to stress. It is difficult to correctly cut the carotid arteries through the cervical spinal cord to induce brain death within 30 s (Anil et al., 2000; Ting et al., 2023). In addition, cervical spine sticking might have resulted in shorter wounds, which reduce the rate of blood loss and delay brain death, potentially increasing stress and depleting muscle glycogen (Anil et al., 2000). The high pH_{24} of meat from pigs on the SUFs treatments versus the commercial diet, throat sticking treatment might be partly due to the higher dietary protein and fat content reported for these treatments. Such protein-rich and energy-dense diets have been found to lower muscle glycogen levels, leading to reduced lactic acid accumulation in pork, particularly when fed with diets low in digestible carbohydrates (Bee et al., 2006; Li et al., 2015; Rosenvold et al., 2003).

The higher meat lightness values observed in the SUFs treatments particularly kitchen-bakery-vegetable, cervical spine sticking treatment might be ascribed to higher IMF values and short-term preslaughter stress due to improper handling during cervical spine sticking. Preslaughter stress may have resulted in faster muscle pH decline while the carcass temperatures were still high causing increased myofibril degradation, leading to greater light dispersion through the muscle (Djimsa et al., 2022; King et al., 2023). The lower redness values of pork from pigs fed the commercial diet and slaughtered by throat sticking, in contrast to other SUF-based treatments, could be due to lower pH_{24} reported for the former treatment, which may have limited the oxygenation of deoxymyoglobin (purple) to oxymyoglobin (cherry red (King et al., 2023). The lower pork redness values for the kitchen-bakery-vegetable waste-based diet, cervical spine sticking treatment compared to the bakery-dairy waste-based diet, throat sticking treatment could be attributed to the high amount of residual blood in the muscle due to inadequate bleeding of cervical spine sticking method (Kaboshio et al., 2020). A high proportion of haemoglobin in muscle results in browning at blooming (King et al., 2023).

The high drip loss in pork from pigs on the kitchen-bakery-vegetable waste-based diet, cervical spine sticking treatment may be attributed to the lower pH_{45} and high temperatures at 45 min. These preslaughter stress-related conditions may have been induced by the cervical sticking method as discussed earlier leading to increased denaturation of myofibrils and reduced water holding capacity. Approximately 85 % of meat moisture is bound to myofibrils, which degrade during apoptosis, thereby reducing water-holding capacity (Devi et al., 2019; Pearce et al., 2011). The lower cooking loss values of pork from pigs on the kitchen-bakery-vegetable waste-based diet, cervical spine sticking treatment and the commercial diet, throat sticking treatment were expected, as meat has a specific fixed amount of moisture content. When a significant amount of water is lost as drip loss, further degradation of myofibrils by cooking will naturally release less water (Pearce et al., 2011). The low cooking loss of pork observed in commercial diet, throat sticking treatment could partly be explained by the low IMF content reported for this diet (Pearce et al., 2011; Warner et al., 2021). Additionally, the higher shear force values for the commercial diet, throat sticking treatment compared to the other treatments could be associated with low pH_{24} that may have reduced proteolytic enzyme activity (Agbeniga & Webb, 2018).

The high muscle temperature at 45 min and lower pH_{45} observed in the non-stunned pigs might be ascribed to stress caused by increased agitation during preslaughter handling (Van Der Wal et al., 1999). The higher pH_{24} values for the gun-stunned versus non-stunned carcasses, suggest that the former stunning method could have reduced preslaughter stress, resulting in slower glycogen breakdown and lower lactic acid accumulation (Driessen et al., 2020). The high cooking loss values and low shear force values of non-stunned carcasses may be explained by the rapid decline in pH due to accelerated glycolysis, which could have increased enzymatic myofibril degradation (Agbeniga & Webb, 2018; Djimsa et al., 2022). The disintegration of myofibril reduces water-holding capacity, which consequently increases cooking loss and tenderness (Agbeniga & Webb, 2018; Djimsa et al., 2022). The lower pH_{24} values for the non-stunned pork could have reduced deoxymyoglobin oxygenation to metmyoglobin (Djimsa et al., 2022; King et al., 2023), resulting in higher meat redness values than those reported for the gun-stunned pork.

The high total FA content in pork from pigs fed the homemade grain-based and bakery-dairy diets may be associated with the high dietary DM and energy contents in these diets, respectively. Dietary DM and energy contents have been positively correlated with DM and energy intake and, consequently, fat deposition (Halas & Babinszky, 2010). The elevated levels of total PUFA, individual and total *n*-6 PUFA in pork from pigs fed the homemade grain-based diet reflect the high linoleic acid (18:2*n*-6) contents in the diet and the overall FA contents in the meat as reported previously (Hoehne et al., 2012; Realini et al., 2021). Linoleic acid is a precursor for desaturase and elongase enzymes in the endogenous biosynthesis of long-chain *n*-6 PUFA in the muscle (Ponnampalam et al., 2021). Similarly, the elevated contents of ALA and total *n*-3 PUFA in pork from pigs fed the kitchen-bakery-vegetable waste-based diet are consistent with the dietary contents of ALA from vegetables and herbs. Longer-chain *n*-3 PUFA are enzymatically transformed from ALA endogenously and positively influence human health (Khan et al., 2023; Ponnampalam et al., 2021).

The increased contents of RA and *c*12,*t*10–18:2 in pork from pigs fed the homemade grain-based and bakery-dairy waste-based diets could be attributed to dietary CLA found in dairy products, such as milk, whey pellets, ice cream and cheese, as well as the high meat FA contents. Conjugated linolenic acids are products of the rumen biohydrogenation process that occurs in ruminants (Vahmani et al., 2020). Linoleic acid and its conjugated dienoic isomers such as RA and *c*12,*t*10–18:2 have been associated with many human health benefits, including reduction of cardiovascular complications, various cancers, type 2 diabetes, obesity and many degenerative diseases (Badawy et al., 2023; Khan et al., 2023). Notably, pork from pigs fed the homemade grain-based diet had RA (6.88 mg/100 g) levels above 5.8 mg/100 g required from natural sources to provide human health benefits (Benjamin et al., 2015; Lehnen et al., 2015). The high levels of most individual and total MUFA and SFA in pork from pigs fed the homemade grain-based and bakery-dairy waste-based diets may be largely explained by their high dietary and meat FA contents.

5. Conclusions

The homemade grain-based diet produced heavier carcasses compared to the other SUF-based diets. Additionally, SUF-based diets yielded pork with higher fat content and a superior FA profile than pork from large-scale commercial farms. The kitchen-bakery-vegetable waste-based diet, cervical spine treatment yielded less desirable pork physical quality attributes. However, stunning of pigs on SUFs improved the physical quality attribute of pork. Notably, the current study was limited by unbalanced experimental designs, confounding variables and small sample size which were difficult to control under smallholder urban pig production conditions. Nonetheless, it was concluded that carcass characteristics and fatty acid contents of pigs reared and slaughtered on SUFs could be enhanced by feeding a homemade based diet while pork physical quality may be enhanced by a homemade based diet, throat sticking treatment and stunning. Further investigation into the preslaughter handling, slaughter hygiene, meat safety and marketing practices as well as consumer preferences and acceptance of pork from pigs raised and slaughtered on SUFs using non-confounding variables, large sample size and balanced designs could be valuable.

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Data availability

Data will be made available on request through corresponding author.

Ethical approval

The Stellenbosch University Research Ethics Committee: Animal Care and Use provided ethical approval (REC: ACU-2020-17166) for the use and care of animals. The South African Department of Agriculture, Land Reform and Rural Development granted permission (12/11/1/4/1/1835 HP) to conduct research following Section 20 of the Animal Diseases Act 35 of 1984 (RSA, 1984).

Declaration of consent for publication

Not applicable.

Ethics statement

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CRediT authorship contribution statement

Rebecca M. Mathobela: Writing – original draft, Investigation, Formal analysis, Data curation. **Obert C. Chikwanha:** Writing – review & editing. **Chenaimoyo L.F. Katiyatiya:** Writing – review & editing. **Farouk Semwogerere:** Writing – review & editing. **Annelin H. Molotsi:** Writing – review & editing, Supervision, Funding acquisition. **Munyaradzi C. Marufu:** Writing – review & editing, Supervision, Funding acquisition. **Phillip E. Strydom:** Writing – review & editing, Supervision, Funding acquisition. **Cletos Mapiye:** Writing – review & editing, Visualization, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest including financial or personal relationships that may negatively affect the publication of this work.

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