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Fatty Acid Profiling of South African A2 Beef from the Same Feeding Regime through Fat Colour

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ABSTRACT

Background: The onset of an industrial shift from grass to grain-supplemented feed has resulted in a rapid change in human diets, specifically in the ratio of n-6 to n-3 fatty acids; where saturated fats and n-6 fatty acid consumption increased at the expense of n-3 fatty acids. Although recent reports on global nutrition put emphasis on health-related fatty acids, the profiling of fat and fatty acids from different breeds reared by different farmers within the same feeding regime is not efficient.

Methods: Fat colour-related proximate fractions (total extractable intramuscular fat, Fat-Free Dry matter and Moisture content) and fatty acid profiles of Bonsmara, Beefmaster, Brangus, Hereford and Simbra A2 steers from different feedlot systems were evaluated.

Result: Breed affected pentadecyclic, total saturated fatty acids (SFA) and docosahexanoic. Hereford had high pentadecyclic and SFA content while Simbra had high docosahexanoic content. Differences in SFA, monounsaturated fatty acids, polyunsaturated fatty acids, n-6, n-3, fatty acid ratios and desaturase index were observed between the white, creamy-white and creamy carcass fat colours. This study has shown that breed synthetic pathways and different feed ingredients which cause differences in the fatty acid composition of beef animals from feedlot-based production systems can be reflected through fat colour.

Key words: Breed, Desaturase index, Feedlot, Human diets, n-3, n-6.

INTRODUCTION

There has been a shift in livestock production systems from grass to grain-supplemented feed (Dunbar *et al*., 2016). Consequently, at the onset of this industrial shift, there was a rapid change in diets, specifically in the ratio of n-6 to n-3 fatty acids in human diets; where saturated fats and n-6 fatty acid consumption increased at the expense of n-3 fatty acids (Kim *et al*., 2015; Dunbar *et al*., 2016). As a result, the high intake of n-6 resulted in a change from a balanced 1:1 to 20:1 n-6: n-3 fatty acid ratio presently or even higher (Simopoulos, 2016). This resulted in the prevalence of obesity and increased risk of cardiovascular disorders (CVD) in most developing countries (Kim *et al*., 2015; Simopoulos, 2016).

Comparison of fatty acids between Feedlot and Pasture-based systems has over the years been a point of emphasis in research, particularly because, fatty acid profiling is a crucial factor (Lucarini *et al*., 2018) related to human health. However, although recent reports on global nutrition are putting more emphasis on health-related fatty acids, the profiling of fat and fatty acids from different breeds reared by different farmers within the same feeding regime is not efficient, particularly within the feedlot-based production systems where most of the meat consumed comes from. Nonetheless, different ingredients in finishing diets of different feedlot systems can affect the fatty acid composition of meat from this feeding regime (Morrill *et al*., 2017).

Likewise, the breed synthetic pathways can also affect how the animals accumulate fatty acids and later affect the fatty acid composition of meat produced, even if animals are of the same feeding system. However, it is often difficult to profile the fatty acid composition of each carcass or cut at the slaughter line in abattoirs of most developing countries like SA, especially considering that it is out of the capacity and/or ability of their meat classification systems to perform the practice. For that reason, non-sophisticated methods to profile fatty acids that can be feasible during slaughter need to be explored by researchers in the meat industry. Thus, the present study evaluated the proximate composition and fatty acid profile in relation to the slaughter carcass fat colour.

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MATERIALS AND METHODS

Ethics consideration

Consent to carry out the study was granted by the University of Fort Hare Research Ethics Committee with reference number MUC411SSOJ01.

Study site

The study was conducted in 2018-19 at the Elliot brothers high throughput abattoir in East London at the Buffalo City

Metropolitan Municipality of the Eastern Cape Province, Republic of South Africa (RSA). The abattoir operates under the standard commercial abattoir procedures and complies with the stipulations of the Meat Safety Act (Act No.40 of 2000) which created an official system of meat inspection to provide measures in promoting meat safety and the safety of animal products; as well as regulations set by the Agricultural Products Standards Act no 119 of 1990 for classification of meat intended for sale in the Republic of South Africa.

Study animals and slaughter procedure

Forty-five (n=45) A2 class steers of 5 breed types (Bonsmara (11), Beef master (6), Brangus (5), Hereford (9) and Simbra (14) typically processed in different South African feedlots were studied. The animals were humanely slaughtered following the standard commercial procedures, where a captive bolt stunning method was used followed by cutting a jugular vein with a sharp knife while the animal was hoisted and suspended by its hind legs.

Sample collection

Meat samples of approximately 2.5 kg were harvested from the *longissimus thoracic et lumborum* (LTL) muscle on the left side of each carcass between the 10th rib and the third lumbar vertebra 24 hours post-slaughter. One hundred gram (100 g) thick subsamples from the LTL muscle were vacuum packed into impermeable plastic bags and stored in a cooler box filled with ice packs pending the fatty acid analysis which was done at the University of Free State, SA.

Fat colour measurements

Measurements of fat colour were taken at the P8 site, the site used for fat depth measurement (AUS- MEAT 1987) using a Minolta colorimeter (BYK-Gardner 6692 colour guide 45/0 glass sealed) with three-dimensional L* a* b* colour coordinates as recommended by CIE (1978) with b* being the yellowness/blueness. Thus, the b* value was considered the ideal objective measurement of the fat yellowness in the present study with b* (1-10) considered white fat, b* (11-20) creamy white and b* (21-30) creamy. Measurements were taken three times on the hot carcasses following the carcass wash and the average of the three measurements was recorded. Areas of fat exhibiting blood splash, bruising, or air bubbles at the P8 site were excluded from the measurement.

Fatty acid profile determination

Total lipids from muscle samples were quantitatively extracted according to the method of Folch *et al*. (1957), using chloroform and methanol in a ratio of 2:1. An antioxidant, butylated hydroxytoluene was added at a concentration of 0.001 % to the chloroform: methanol mixture. A rotary evaporator was used to dry the fat extracts under vacuum and the extracts were dried overnight in a vacuum oven at 50°C, using phosphorus pentoxide as a moisture adsorbent Qwele *et al*. (2013). Total extractable intramuscular fat was determined gravimetrically from the extracted fat and expressed as percent fat (w/w) per 100 g tissue Qwele *et al*. (2013). The fat-free dry matter (FFDM) content was determined by weighing the residue on a pre-weighed filter paper, used for Folch extraction, after drying. By determining the difference in weight, the FFDM could be expressed as % FFDM (w/w) per 100 g tissue.

The moisture content of the muscle and BF was determined by subtraction (100% - % lipid - % FFDM) and expressed as % moisture (w/w) per 100 g tissue. The extracted fat was stored in a poly top (glass vial, with push-in top) under a blanket of nitrogen and frozen at -20°C pending fatty acid analyses. A lipid aliquot (±30 mg) muscle lipid was converted to methyl esters by base-catalysed transesterification, in order to avoid CLA isomerisation, with sodium methoxide (0.5 M solution in anhydrous methanol) during 2 h at 30°C, as proposed by Park *et al*. (2001), Kramer *et al*. (2002) and Alfaia *et al*. (2007). Fatty acid methyl esters (FAMEs) from feed, muscle and subcutaneous fat were quantified using a Varian 430 flame ionization GC, with a fused silica capillary column, Chrompack CPSIL 88 (100 m length, 0.25 mm ID, 0.2 µm film thicknesses). Analysis was performed using an initial isothermic period (40°C for 2 minutes). Thereafter, the temperature was increased at a rate of 4°C/minute to 230°C. Finally, an isothermic period of 230°C for 10 minutes followed. FAMEs n-hexane (1 µl) were injected into the column using a Varian CP 8400 Autosampler. The injection port and detector were both maintained at 250°C. Hydrogen, at 45 psi, functioned as the carrier gas, while nitrogen was employed as the makeup gas. Galaxy Chromatography Data System Software recorded the chromatograms.

Fatty acid methyl ester samples were identified by comparing the retention times of FAME peaks from samples with those of standards obtained from Supelco (Supelco 37 Component Fame Mix 47885-U, Sigma-Aldrich Aston Manor, Pretoria, South Africa). Conjugated linoleic acid (CLA) standards were obtained from Matreya Inc. (Pleasant Gap, Unites States). These standards included: cis-9, trans-11 and trans-10, cis-12-18:2 isomers. Fatty acids were expressed as the proportion of each individual fatty acid to the total of all fatty acids present in the sample. Fatty acid data were used to calculate the following ratios of FAs: total SFAs total MUFAs; total PUFAs; PUFA/SFA; ∆9 desaturase index (C18:1c9/C18:0); total omega-6; total omega-3; the ratio of omega-6 to omega-3 (n-6)/(n-3) FAs. Atherogenicity index (AI) was calculated as:

$$AI = \frac{C12:0 + 4 \times C14:0 + C16:0}{MUFA + PUFA}$$

Chilliard *et al*. (2003)

Statistical analysis

Data was analysed using general linear model procedure (PROC GLM) of JMP 9.0 (SAS Institute, 2009) to test the effect of breed and fat colour on fatty acid profile. The following model was used:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \varepsilon_{ijk}$$

Where,
Y_{ijkl} = Response variable (fatty acid profile).
μ = Overall mean.
α_i = i^{th} effect of breed.
ε_j = j^{th} effect of fat colour.
ε_{ijk} = Random error.

Principal component analysis (PCA) of XLSTAT version 2018.5 statistical software for Excel was used to test the strengths of relationships between fat colour, proximate, individual fatty acids, fatty acid ratios and health indices. Mean separation was conducted using the least significant difference (LSD) method.

RESULTS AND DISCUSSION

Breed had a significant effect (P<0.05) on some fatty acids (Table 1). Notable breed effects were observed in pentadecyclic (C15:0), docosahexanoic (C22:6c4, 7, 10, 13, 16, 19) and total saturated fatty acids (SFA). While other

Table 1: Effect of breed on Fatty acid composition.

Fatty acids	Beef master (n=6)	Bonsmara (n=11)	Brangus (n=5)	Hereford (n=9)	Simbra (n=14)
Saturated fatty acids (SFA)					
Myristic C14:0	1.58±0.269	1.55±0.199	1.75±0.295	1.84±0.220	1.77±0.176
Pentadecylic C15:0	0.19 ^{a} ±0.036	0.24 ^{a,b} ±0.027	0.28 ^{a,b} ±0.040	0.29 ^{b} ±0.030	0.23 $^{a.b}$ ±0.024
Palmitic C16:0	20.97 ±0.981	20.83±0.724	21.44±1.075	22.20±0.801	22.2±0.642
Margaric C17:0	2.32±0.238	2.36±0.176	2.22±0.261	2.13±0.194	2.30±0.156
Stearic acid C18:0	14.7±1.359	17.1±1.003	16.2±1.488	17.1±1.109	17.03±0.89
Arachidic C20:0	0.04±0.902	0.06±0.666	0.06±0.988	1.72±0.736	0.06±0.590
Heneicosanoic C21:0	0.65±0.110	0.59±0.081	0.52±0.120	0.51±0.090	0.60±0.072
Total saturated fatty acids (SFA)	41.6^{a}±2.000	43.9 ^{a,b}±1.477	43.5 ^{a,b} ±2.191	46.70^{b}±1.633	45.30 ^{a,b}±1.210
Mono unsaturated fatty acids (MUFA)					
Myristoleic C14:1c9	0.41±0.086	0.28±0.063	0.38±0.094	0.36±0.070	0.32±0.056
Palmitoleic C16:1c9	2.80±0.340	2.18±0.251	2.56±0.372	2.36±0.278	2.14±0.223
Heptadecenoic C17:1c10	0.22±0.049	0.16±0.036	0.20±0.053	0.13±0.040	0.21±0.032
Oleic C18:1c9	34.02±2.524	34.3±1.86	33.8±2.77	32.3±2.061	32.5±1.65
Vaccenic C	3.04±0.539	2.86±0.398	3.00±0.591	3.19±0.440	2.93±0.353
Erucic C22:1c13	0.69±0.119	0.49±0.088	0.57±0.130	0.50±0.097	0.52±0.078
Total mono unsaturated fatty acids (MUFA)	41.3±3.083	40.44±2.28	40.70±3.377	39.03±2.517	38.9±2.018
Poly unsaturated fatty acids (PUFA)					
Elaidic C18:1t9	0.06±0.125	0.15±0.092	0.21±0.137	0.21±0.102	0.27±0.082
Nonoadecanoic C19:0	1.14±0.182	1.09±0.134	0.96±0.199	0.87±0.148	1.08±0.119
Linolelaidic C18:2t9,12 (n-6)	0.04±0.045	0.03±0.033	0.03±0.049	0.11±0.037	0.03±0.030
Linoleic C18:2c9,12 (n-6)	10.9±2.46	10.7±1.815	10.6±2.69	9.07±2.006	10.3±1.609
á-Linolenic C18:3c9,12,15 (n-3)	0.95±0.222	0.87±0.164	0.74±0.243	0.85±0.181	0.75±0.145
Conjugated linoleic acid (CLA)	0.21±0.049	0.23±0.036	0.22±0.054	0.21±0.040	0.18±0.032
Eicosadienoic C20:2c11,14 (n-6)	0.01±0.012	0.02±0.009	0.02±0.014	0.03±0.010	0.02±0.008
Eicosatrienoic C20:3c8,11,14 (n-6)	0.05±0.029	0.05±0.022	0.06±0.031	0.06±0.024	0.05±0.019
Arachidonic C20:4c5,8,11,14 (n-6)	3.37±0.581	2.76±0.429	3.05±0.637	2.66±0.474	2.93±0.380
Docosadienoic C22:2c13,16 (n-6)	0.03±0.012	0.01±0.009	0.00±0.014	0.01±0.010	0.02±0.008
Eicosopentaenoic C20:5c5,8,11,14,17 (n-3)	0.57±0.164	0.34±0.121	0.33±0.180	0.44±0.134	0.48±0.107
Docosapentaenoic C22:5c7,10,13,16,19 (n-3)	1.00±0.246	0.67±0.182	0.71±0.270	0.81±0.201	0.95±0.161
Docosahexanoic C22:6c4,7,10,13,16,19 (n-3)	0.05^{a,b}±0.029	0.01^{a}±0.022	0.02 ^{a,b} ±0.032	0.03 ^{a,b} ±0.024	0.07^{b}±0.019
Total poly unsaturated fatty acids (PUFA)	17.1±2.79	15.7±2.064	15.8±3.061	14.3±2.28	15.8±1.83
Total Omega- 6 Fatty Acids (n-6)	14.5±2.75	13.8±2.027	14.03±3.007	12.1±2.241	13.57±1.80
Total Omega- 3 Fatty Acids (n-3)	2.57±0.611	1.88±0.451	1.80±0.67	2.13±0.499	2.25±0.400
PUFA:SFA	0.42±0.064	0.36±0.047	0.36±0.070	0.32±0.053	0.35±0.042
PUFA/MUFA	0.43±0.121	0.45±0.090	0.47±0.133	0.43±0.100	0.43±0.079
n-6/n-3	8.73±3.624	9.93±2.68	11.9±3.970	8.58±2.96	11.3±2.37
Atherogenicity index	0.47±0.054	0.49±0.040	0.50±0.060	0.57±0.044	0.54±0.036
Desaturase index	2.33±0.284	2.09±0.210	2.22±0.311	2.07±0.232	2.02±0.186

$^{a,\ b}$ Means with different superscripts within the row are different at P<0.05; Means with no superscripts are similar (P>0.05).

breeds were similar to each other in C15:0 composition, Beef master differed from Hereford with Hereford having a higher content and Beef master having the lowest content of C15:0. A similar trend was observed for SFA. In docosahexanoic, notable differences (P<0.05) were observed between Bonsmara and Simbra with Simbra having the highest content while Bonsmara had the lowest content.

These results show that while some breeds in the same production system might have a similar ability to synthesize and accumulate some fatty acids, some have different synthesis pathways. These results agree with Bartoň, *et al*. (2016) who reported that, unlike meat from non-ruminant animals, the fatty acid composition of beef is not necessarily dependent on diet, but is also determined by key lipogenic enzymes in fatty acid synthesis pathways. Thus, the fatty acid composition of meat has to be judged not only against animal diet but also against breeds.

Furthermore, fatty acid composition differed with fat colour in the present study (Table 2). Notable fatty acid differences (P<0.05) among white, creamy-white and creamy fat colour were observed in total saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty

Table 2: Effect of fat colour on fatty acid composition.

Fatty acids	White b* (1-10) n=15	Creamy white b* (11-20) n=15	Creamy b* (21-30) n=15
Saturated fatty acids (SFA)			
Myristic C14:0	1.90±0.161	1.78±0.204	1.66±0.200
Pentadecylic C15:0	0.23±0.222	0.27±0.280	0.27±0.028
Palmitic C16:0	22.1±0.630	21.6±0.795	22.7±0.782
Margaric C17:0	2.14±0.155	2.22±0.196	2.43±0.193
Stearic acid C18:0	18.4^{a}±0.868	16.9 ^{a,b}±1.10	15.2^{b}±1.078
Arachidic C20:0	0.27±1.032	2.36±1.303	0.05±1.28
Heneicosanoic C21:0	0.53±0.062	0.54±0.078	0.57±0.077
Total saturated fatty acids (SFA)	46.6±1.62	46.5±2.047	43.90±2.013
Mono unsaturated fatty acids (MUFA)			
Myristoleic C14:1c9	0.37±0.071	0.33±0.081	0.46±0.80
Palmitoleic C16:1c9	2.10^{a}±0.295	2.35^{a,b}±0.336	2.75^{b}±0.332
Heptadecenoic C17:1c10	0.16±0.042	0.14±0.047	0.15±0.047
Oleic C18:1c9	30.9^{a}±2.106	34.6^{a,b}±2.40	36.1^{b}±2.370
Vaccenic C18:1c7 t11	2.50^{a}±0.473	3.46^{b}±0.538	3.53^{b}±0.533
Erucic C22:1c13	0.38±0.088	0.45±0.100	0.39±0.099
Total mono unsaturated fatty acids (MUFA)	36.6^{a}±2.557	41.5$^{a,\ b}$±2.91	43.7^{b}±2.88
Poly unsaturated fatty acids (PUFA)			
Elaidic C18:1t9	0.16±0.079	0.17±0.079	0.25±0.079
NonoadecanoicC19:0	0.84±0.124	0.87±0.141	0.90±0.140
Linolelaidic C18:2t9,12 (n-6)	0.04±0.040	0.09±0.046	0.06±0.046
Linoleic C18:2c9,12 (n-6)	12.1^{a}±1.950	8.13^{b}±2.22	7.26^{b}±2.19
á-Linolenic C18:3c9,12,15 (n-3)	0.47^{a}±0.186	0.78^{a,b}±0.212	0.91^{b}±0.209
Conjugated linoleic acid (CLA)	0.16^{a}±0.037	0.22^{b}±0.042	0.25^{b}±0.042
Eicosadienoic C20:2c11,14 (n-6)	0.03^{a}±0.011	0.02^{a,b}±0.012	0.01^{b}±0.012
Eicosatrienoic C20:3c8,11,14 (n-6)	0.07^{a}±0.025	0.03^{b}±0.028	0.04^{a,b}±0.028
Arachidonic C20:4c5,8,11,14 (n-6)	2.17±0.392	2.59±0.466	2.40±0.441
Docosadienoic C22:2c13,16 (n-6)	0.003^{a}±0.011	0.02^{b}±0.012	0.02^{b}±0.012
Eicosopentaenoic C20:5c5,8,11,14,17 (n-3)	0.18±0.134	0.35±0.152	0.41±0.151
Docosapentaenoic C22:5c7,10,13,16,19 (n-3)	0.44±0.200	0.69±0.228	0.80±0.225
Docosahexanoic C22:6c4,7,10,13,16,19 (n-3)	0.01±0.027	0.05±0.031	0.03±0.031
Total poly unsaturated fatty acids (PUFA)	15.6±2.056	13.00±2.339	12.19±2.314
Total Omega-6 fatty acids (n-6)	14.5^{a}±2.110	11.1^{a,b}±2.399	10.04^{b}±2.374
Total Omega-3 fatty acids (n-3)	1.09^{a}±0.491	1.87^{a,b}±0.558	2.15^{b}±0.552
PUFA:SFA	0.33±0.047	0.30±0.054	0.29±0.053
PUFA/MUFA	0.47^{a}±0.094	0.32^{a,b}±0.107	0.26^{b}±0.106
n-6/n-3	18.1^{a}±3.028	13.4^{a,b}±3.443	10.6^{b}±3.407
Atherogenicity index	0.61±0.040	0.56±0.045	0.57±0.045
Desaturase index	1.71^{a}±0.240	2.09^{a,b}±0.273	2.44^{b}±0.270

^{ab} Means with different superscripts within the row are different at P<0.05; Means with no superscripts are similar (P>0.05)

acids (PUFA), total omega 6 and 3 fatty acids, fatty acid ratios and desaturase index. In most cases, carcasses with white fat colour had a fatty acid composition different from those with creamy fat colour, while fatty acid composition of carcasses with creamy-white fat colour was sometimes not different from either white or creamy fat carcasses. This observation was seen in stearic acid (C18:0), oleic (C18:1c9), MUFA, α-linolenic (C18:3c9, 12, 15), eicosadienoic (C20:2c11, 14), total omega- 6 fatty acids (n-6), total omega-3 fatty acids (n-3), PUFA/MUFA, n-6/n-3 and desaturase Index. On the other hand, in vaccenic (C18:1c7 t11), linoleic C18:2c9, 12 (n-6), conjugated linoleic acid (CLA) and docosadienoic C22:2c13, 16 (n-6), the fatty acid composition of carcasses with white fat colour differed from both creamy-white and creamy fat colour, while the latter were similar.

The general trend shown in this study was that carcasses with white fat colour had more omega-6 and low omega-3 fatty acids, with omega-3 fatty acids increasing with the intensification of the creamy fat colour. While the animals in the present study were all from feedlot-based systems, the differences in fat colour enhanced the differences in fatty acid composition. Although feed ingredients were not investigated in this study, this could be attributed to different ingredients in finishing diets that affect the fatty acid composition of animals from different feedlot systems (Morrill *et al*., 2017) and the breed synthesis pathways.

A yellowish or rather creamy fat colour is perceived to be unhealthy and downgraded in many countries like South Africa, however, the present results agree with Dunne *et al*. (2009) who indicated that there is supporting evidence that it is associated with healthy fatty acids and antioxidants in beef. For instance, in the present study, white fat carcasses had high myristic and palmitic fatty acids which are associated with an increased risk of cardiovascular diseases Siri-Tarino *et al*. (2010). While on the other hand, creamy fat carcasses had high n-3, α Linolenic, CLA and vaccenic fatty acids; which are associated with the prevention of cardiovascular diseases, cancers, heart diseases, obesity, diabetes, boosting the immune system and development of brain and retinal tissues (De la Torre *et al*., 2006).

Nevertheless, careful consideration of fat colour should also be observed beyond the individual fatty acids. This is mainly because, carcasses with a creamy fat colour had a high desaturase index, while those with white fat colour had a high atherogenicity index (AI) in the present study. The desaturase and atherogenicity indices are predictors of metabolic diseases and cardiovascular disorders, respectively (Parinita 2012). Thus, the association of creamy fat colour with a high desaturase index and white fat colour with high AI, may suggest that the higher the intensity of the whitish or creamy fat colour, the higher the risk of metabolic and cardiovascular disorders. Therefore, creamy-white fat meat may pose less health risk than white or creamy-fat meat since it is in-between. Furthermore, there was a positive linear relationship (Fig 1) between the desaturase index and fat colour (r=0.414; P=0.005) while fat colour was strongly associated with CLA and Vaccenic in the present study.

Fat colour and desaturase index were also shown to be strongly associated with unsaturated fatty acids more specifically the MUFAs. Shirouchi *et al*. (2014) highlighted that the accumulation of MUFAs and lower SFA enhances the desaturation activity which also increases the risk of cardiovascular diseases (CVD). Thus, the concentration of feed with high MUFAs should be controlled in the diets of animals to reduce diseases associated with fat colour. The AI on the other hand had a positive linear relationship with % fat (r=0.559; P<0.0001) where the higher the % fat the higher the atherogenicity index. The % fat and AI were shown to be more influenced by saturated fatty acids in particular the palmitic and myristic fatty acids, respectively. These results agree with those reported by Pilarczyk and Wójcik (2015) that the AI is an indication of the nutritional value and consumer health of intramuscular fat. For instance, the dietary intake of saturated fatty acids (SFA) is highly associated with increased CVD risk and blood cholesterol

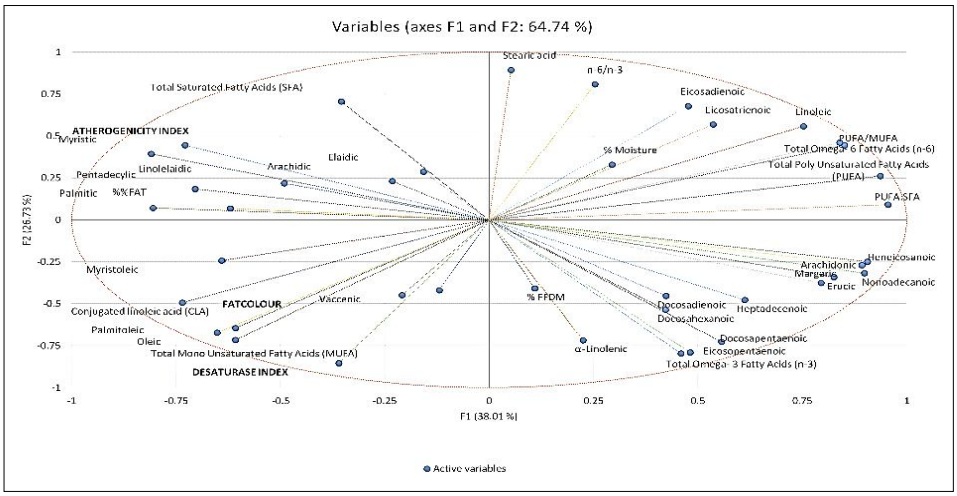

Fig 1: Relationship between fat colour, fat content and fatty acid profile.

(Shirouchi *et al*., 2014). Thus, animal feed with high contents of SFA should be controlled to gauge the amount of fat in meat consumed.

Moreover, the AI of the beef muscles in the present study ranged from 0.4 to 0.6, suggesting higher values than the recommended. AI values between -0.3 and 0.1 are associated with low CVD, AI of 0.1 to 0.24 with medium and AI values >0.24 associated with high CVD risk (Dobiášová 2006). Thus, consumption of meat from beef animals with AI ranging from 0.4-to-0.6 may increase the risk of consumers being exposed to CVD. Lastly, among the SFAs, palmitic acid was the predominant followed by stearic acid with mean values of 21.5 g/100 g total fat and 16.5 g/100 g total fat respectively.

These results are similar to those reported by Lucarini *et al*. (2018) although the stearic acid content is higher in the present study. Among the MUFAs, oleic [C18:1c9) was predominant followed by vaccenic (C18:1c9) with mean values of 33.4 g/100 g total fat and 2.98 g/100 g total fat respectively. While among the PUFAs, linoleic [(C18:2c9, 12 (n-6)] was predominant followed by arachidonic [(C20:4c5, 8, 11, 14 (n-6)] with mean values of 10.34 g/100 g total fat and 2.95 g/100 g total fat. Moreover, the distribution of fatty acid classes was in the following descending order of concentrations: SFA > MUFA > PUFA, with mean values of 44.2:40.1:15.8, respectively. These results are contradictory to those of Lucarini *et al*. (2018) who indicated a descending order of MUFA>SFA>PUFA. The present study shows that meat from some SA feedlot-based systems has high SFAs and low PUFAs, which contradicts the recommended consumer dietary patterns which should be lower in SFA and richer in unsaturated fats. This increases the risk of consumers' susceptibility to related health problems since SFA have long been considered risk factors to human health.

Also, the n-6: n-3 ratio in the present study was 12:1 contradicting the recommended dietary n-6: n-3 fatty acid ratio of 4:1. Muchenje *et al*. (2009) and Blanco *et al*. (2010) have indicated that unlike concentrate feeding, forage feeding increases the content of n-3 PUFAs and reduces the SFA content in meat. The 2015 Scientific report on Dietary Guidelines also indicated that dietary patterns lower in SFA and richer in unsaturated fats are favourable in reducing the risk of cardiovascular diseases. Thus, in as much as most SA beef is produced through feedlot systems, there is a need for feed manipulation in the ingredients of feedlot-based systems while also considering the synthetic pathways of different breeds, to meet the dietary requirements of consumers.

CONCLUSION

The present study has shown that breed synthetic pathways and different feed ingredients cause differences in the fatty acid composition of beef animals from feedlot-based production systems and these can be reflected through fat colour profiling in the slaughter line. Further research is, however, recommended on ways of manipulating feed ingredients of feedlot-based systems to meet the healthy dietary requirements of consumers. The feed manipulation should be done considering different breed synthetic pathways.

Conflict of interest: None.

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