Fatty acids in beef from grain- and grass-fed cattle: the unique South African scenario

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Abstract

Objective: Different fatty acids elicit different responses in the human body once ingested. Although red meat is often considered to be a source of fatty acids which has a negative impact on human health, many studies have reflected variability in the quantity and quality of fatty acids found in red meat produced on different production systems in different countries. This study evaluated the fatty acid profile of beef, produced by the grass- and grain-fed production systems practised in South Africa.

Design: Data are reported as a percentage of lipid per 100 g total fat to enable a comparison with international findings. Furthermore, the findings are translated into edible meat portions, taking fat trimming (often associated with red meat intake) into consideration in order to determine the contribution which the different products can make to the human diet.

Subjects and setting: Three cuts of beef from cattle from four production groups were sampled and the fatty acid composition analysed for the meat and fat fractions.

Results: Notable differences were found in the quantity and quality of different fatty acids in beef from the different production systems. When untrimmed, no statistically significant difference was found in the total fat between beef produced on the different production systems. Differences became more significant as trimming was performed. When trimmed of all visible fat, beef from young cattle fed according to a grain-based feeding system contained less total fat (6.96 g), and less saturated fat (2.16 g) per 100 g, than beef produced from their grass-fed counterparts (9.77 g and 3.30 g, respectively). There was a more favourable omega-6 to omega-3 fatty acid ratio, i.e. 2.0–2.5:1.0 for grass-fed cattle, compared to 8–30:1 for grain-fed cattle, irrespective of the degree of trimming. The beef from the grass-fed cattle also contained a higher quantity of conjugated linoleic acid.

Conclusion: A unique classification system for red meat has been implemented in South Africa and dictates the characteristics of the fresh meat that is available to consumers. The results of this study consequently indicate distinctive differences between the fatty acid profile of local red meat and that of beef produce from other countries; often used as a reference for dietary guidance.

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Introduction

The role of fat, and more recently the quality of fatty acids, in the human diet, has enjoyed abundant focus for centuries. Currently, *Progress on Lipid Research* is the journal with the highest impact factor of 12.96 on the ISI Web of Knowledge in the subcategory of Nutrition and Dietetics. In 1850, The Lancet published the Gustonian lectures, presented by Thomas King Chambers, entitled, *Corpulance, or excess of fat in the human body: its relations to chemistry and physiology, its bearings on other diseases and the value of human life, and its indications for treatment.*[1] Since the early 1900s, the role of individual fatty acids in human health has been investigated and published.[2,3] The first expert consultation by the World Health Organization and the Food and Agriculture Organization of the United Nations on fats and oils in human nutrition was held in 1977, with the second in 1993 and third in 2008. The time frame of these expert consultations is also tied in to recognition of the increasing global burden of nutrition-related chronic disease.[4] The role of fat in human nutrition (both positive and negative) has been highly debated over time, and increasingly so in recent times with the rise in popularity of high-fat, low-carbohydrate diets.[5]

When dietary intake and the food sources of fatty acid in the human diet are considered, it is well known that animal sources of food, including red meat, often provide a significant proportion of total and saturated fatty acid in the Westernised diet.[6] Red meat can also provide essential fatty acids in notably quantities.[7] Changes in cattle breeding and management, as well as the trimming of visible fat at retail centres or at home has resulted in the availability on the market today of leaner meat cuts with a lower total fat content, and often with a more favourable fatty acid profile.[7]

Different production systems, and especially types of feed, have been shown to significantly alter the fatty acid profile of beef, and research has been published on the fatty acid profiles of beef that has been produced from grass-fed and grain-fed cattle.[8] However, data on the fatty acid profile of edible portions of South African beef from different production (feeding) systems are limited.

An overview of beef production in South Africa

Similar to international trends, beef produced through the provision of a grain-fed diet to cattle has increased in South Africa as it enables producers to respond more efficiently to consumer demand.[9,10] More than 70% of beef that is available to consumers is currently produced in this manner.[11] Typically, weaned calves are sold to feedlots where they are fed a grain-based or concentrated diet for approximately 110 days to obtain the optimum fatness level according to the South African carcass classification system[12] within a relatively short period.[11] This method of production also produces less greenhouse gas emissions.[10,13]

However, some South African producers prefer to produce beef using a grass- or forage-based feeding system as it delivers a product with alternative attributes in line with many other social aspects of sustainable agriculture, such as the production of naturally produced beef, or beef produced from grass-fed cattle.[11]

As with most other grading or classification systems for red meat, to a large extent the South African carcass classification system dictates the attributes and characteristics of locally produced fresh beef produced for the consumer market as it guides the prices that should be paid to the producer. The South African system is unique compared to other global classification or grading systems as it classifies meat according to the amount of visible, subcutaneous (outside) fat on the carcass, as well as the age of the animal.[14]

Since the 1930s, studies on the nutritional and physical composition of South African red meat, together with consumer research, have assisted in guiding the development of the national carcass classification system over time.[15] In 1970, more than 70% of South Africans preferred between 3 mm and 6 mm fat to cover beef roasts, i.e. approximately 6% subcutaneous fat and 18% dissectible carcass fat. It was found in a follow-up survey conducted in 1987 that 77% of the population preferred lower fat cover. Based on these results, the current classification system for South African beef, sheep, lambs and goats was introduced (in 1992).[15] As a baseline consideration, the optimum price is obtained from lean fat cover on the carcass of between 1 mm and 3 mm thickness in South Africa. Producers, irrespective of the production system used, aim to achieve this fat cover prior to slaughter. Breeds and feeding techniques have been adapted over time to produce carcasses with optimal fat cover, while using minimal resources.

As mentioned, grain-based production systems have been formulated to produce beef with optimum characteristics in young animals in a short period. To achieve the optimum fatness level and best price incentive per slaughtered mass on extensive (grass- or forage-based) production systems takes longer than grain finishing. This results in slightly older animals being found on the South African market. In addition to beef produced specifically for the meat market and cattle being slaughtered relatively young, old (culled or retired) animals, often produced from communal or marginal farming systems in South Africa, are also slaughtered for human consumption. The beef products derived from these older carcasses are available on the market as a lower price option for marginalised consumers who dominate the current South African population.[16] Typically, these animals spend their lifetime on grass, but once they reach an age at which they are no longer able to produce offspring efficiently, they are sold to feedlots to be finished on grain for a short period to reach optimal fatness prior to slaughter.

Objective

This study evaluated the fatty acid profile of South Africa beef produced according to the different production systems practised in the country. Globally, important differences in the nutritional profile of agricultural products, such as meat, have been revealed through country-specific research. However, previously data were not available to extrapolate the effect of the feeding regime within the framework of the unique South African carcass classification system on the fatty acid profile of South African beef.

Furthermore, reports in meat science studies have been confined to differences in fatty acids as a percentage of total fatty acid, or as grams per 100 g total fat. To ensure an accurate estimation of the contribution that products can make to the human diet, dietary advice and analyses should reflect red meat as consumed.[9] The fatty acid composition was translated into edible portions in the current study, taking fat trimming into consideration. This additional mode of expression of the results "as consumed" enables translation of the scientific findings into human dietary recommendations.

Method

Sampling

Breed was identified as a controllable factor to minimise variation between the datasets.[17] Cattle from the Bonsmara breed were included in the study. The Bonsmara breed is a locally developed, predominant breed in South Africa. Approximately 70% of the commercial beef herd comprises Bonsmara-type, medium-framed cattle.[13]

Four different production groups were identified, based on typical market share. Group 1 included young grain-fed animals with 0 incisors (permanent teeth). Group 2 included young exclusively grass-fed animals with 1-2 incisors. Group 3 included older animals from exclusive grass-fed systems with 2-6 permanent incisors. Group 4 compromised old animals with ≥ 6 incisors, who had grazed on grass throughout their lives, but were finished off to the desired fatness on a grain-based diet, similar to the procedure followed when culling a retired animal.

Nine carcasses from each group were included in the study, and screened according to their fatness to fall within the optimum leanness of a 1-3 mm subcutaneous fat layer on the prime rib, according to the carcass classification system.[12] The animals were slaughtered and dressed according to standard commercial procedures at the Agricultural Research Council's registered abattoir in Irene, Pretoria. Carcasses were electrically stimulated for 15 seconds (400 V peak, 5 ms pulses at 15 pulses) after exsanguination, and entered the cold room (1-4 °C) 45 minutes thereafter. Carcasses were chilled at 0-3 °C before being processed the day after slaughter.

Physical dissection

Carcasses were sectioned down the vertebral column. Cuts from the left side of each carcass were kept raw for nutritional analysis, while those from the right side were cooked prior to nutritional analysis. The sides were subdivided into the primal carcass cuts, according to the London and home counties cutting techniques, as described by Naudé.[18] The prime rib cut was selected for analysis as it best represents the composition of the carcass.[19] An experienced deboning team was responsible for the physical dissection of the cuts.

Dissection took place in an environmentally controlled deboning room (10 °C). The cuts were weighed and dissected into visible meat, subcutaneous fat (adipose tissue under the skin), intermuscular fat (adipose tissue between the muscles) and bone. Each fraction was weighted and recorded in order to calculate the cut composition. After nutrient analysis, the cut composition was used to calculate nutrient content.

Nutritional analysis

The muscle and fat fractions from three of the same cuts were grouped together as composite samples of muscle and fat for nutritional analysis purposes. These fractions were mixed, cubed, minced twice (using 5 mm, then 3 mm mesh plates), vacuum sealed and frozen. The samples were freeze dried and sent for nutritional analysis to be performed on a double-blind basis at the UP NutriLab, University of Pretoria, and the Department of Microbial, Biochemical and Food Biotechnology, University of the Free State. Proximate analysis of the cuts was carried out to determine:

- *Total moisture:* Official method of analysis 934.01, Association of Official Analytical Chemists (AOAC).[20]
- *Fat (ethanol extracted):* Official method of analysis 954.02, AOAC.
- *Nitrogen:* Official method of analysis 968.06, AOAC.
- *Ash:* Official method of analysis 942.05, AOAC.[20]

A conversion factor of 6.25 was used to calculate the protein content.[21] The method used by Carroll and Conniffe[22] was employed to calculate the physical composition from chemically analysed moisture, protein, ash and lipids, together with the physical dissection data.

Total lipid from the meat sample was quantitatively extracted, according to the method by Folch et al.[23] Total extractable lipid was determined gravimetrically from the extracted fat and expressed as a percentage of the fat per 100 g tissue. A lipid aliquot (20 mg) was converted to methyl ester by base-catalysed transesterification in order to avoid conjugated linoleic acid (CLA) isomerisation.[24,25] Fatty acid methyl esters (FAMEs) from fat were quantified using a Varian® 430-GS flame ionisation, with a fused silica capillary column, i.e. Chrompack® CP-Sil 88 (100 m length, 0.25 mm internal diameter and 0.2 µm film thickness). Analysis was performed using an initial isothermic period (40 °C for two 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. The chromatograms were recorded using Galaxy® chromatography software.

Fatty acid methyl ester samples were identified by comparing the retention times of the FAME peaks from samples with those of standards obtained from the Supelco® 37 Component Fame Mix (47885-U) (Sigma-Aldrich Aston Manor, Pretoria, South Africa). CLA standards were obtained from Matreya LLC, State College, USA. All other reagents and solvents were of analytical grade and obtained from Merck Chemicals, Johannesburg, South Africa.

Statistical analysis

Data were statistically analysed with GenStat® software (2013), using linear mixed models, and employing the residual maximum likelihood procedure outlined in GenStat®. The analysis was used to test for differences between the effects of each group per cut. Fisher's protected least significant differences test at the 1% level was used to separate the means.[26]

Results and discussion

Fatty acid content as a percentage of total fatty acid

Saturated fatty acids

To enable a comparison of the results with the plethora of international and local research on fatty acid composition, the data were expressed as a percentage of fatty acid per total fatty acid (Table I). A statistically significant difference was not found between the total or individual saturated fatty acids (SFAs) in South African beef produced on different production systems, expect for arachidic acid (C20:0). Arachidic acid was not detected in group 1 (grain-fed cattle), while there was a significantly higher percentage of arachidic acid in the two groups finished on pasture compared to that in group 4 (culled animals finished on grain). Little difference in the concentration of SFA between production groups was found in a review by Daley et al.[8] Generally, there was a higher total SFA content in beef from grass-fed cattle compared to grain-fed cattle, a similar relationship to what has been reported in other studies from around the world. However, when compared to these international studies, it can be seen that on average, South African beef fat, irrespective of the production system used, contains a higher percentage of total SFA than that reported in the USA, UK or Argentina (Table I).

The majority of fatty acids (> 30% in all groups) found in South African beef is palmitic acid (C16:0) which could increase total and low-density lipoprotein (LDL) cholesterol.[4] The cholesterol-neutral SFA,[4] stearic acid (C18:0), comprised a notable proportion of the fatty

Table I: The fatty acid composition of South African beef produced on different production systems,* expressed as a percentage of total fatty acid, and compared to international data

Fatty acids	Current study (South Africa)						USA[31]		UK[29]		Argentina[30]	
	G1	G2	G3	G4	p-value	SE	Grass-fed cattle	Grain-fed cattle	Grass-fed cattle	Grain-fed cattle	Grass-fed cattle	Grain-fed cattle
Myristic (C14:0)	5.13	4.82	5.48	5.02	0.510	0.30	2.46	2.79	2.31	2.49	2.19	2.44
Palmitic (C16:0)	31.40	31.60	33.10	31.70	0.580	0.92	24.30	26.70	24.30	23.20	23.10	22.10
Margaric (C17:0)	–	2.03	1.80	1.69	0.090	0.09	1.14	1.34	–	–	1.39	1.69
Stearic (C18:0)	20.00	23.00	21.00	24.30	0.310	1.64	17.40	14.00	15.80	13.70	13.10	10.80
Arachidic (C20:0)	–	0.50^{a}	0.47^{a}	0.28^{b}	0.040	0.05	–	–	–	–	–	–
Myristoleic (C14:1 n-9)	–	–	–	–	–	–	0.38	0.60	–	–	0.48	0.67
Palmitoleic (C16:1 n-7)	3.38	3.83	4.38	3.23	0.060	0.27	2.72	3.46	3.65	3.58	3.35	3.82
Heptadecenoic (C17:1)	–	0.68^{a}	0.68^{a}	0.46^{b}	0.003	0.03	–	–	–	–	0.96	1.63
Elaidic (C18:1 t-9)	5.97^{a}	5.10^{a,b}	4.17^{b}	4.68^{a,b}	0.030	0.33	3.38	1.83	2.50	2.69	3.22	4.35
Oleic (C18:1 n-9)	31.50	26.30	26.90	26.10	0.100	1.49	32.00	39.40	35.90	31.90	31.20	32.80
Eicosenoic (C20:1 n-11)	0.14^{a}	0.49^{c}	0.40^{b,c}	0.31^{a,b}	0.010	0.06	–	–	–	–	–	–
Linoleic (C18:2 n-6)	2.32^{a}	0.91^{b}	0.83^{b}	1.21^{b}	< 0.001	0.13	2.75	2.97	2.50	8.28	3.41	6.19
Gamma-linolenic (C18:3 n-6)	–	0.17	0.20	0.09	0.310	0.03	–	–	0.02	0.05	–	–
Alpha-linolenic (C18:3 n-3)	0.30^{a}	0.73^{c}	0.64^{b,c}	0.50^{b}	< 0.001	0.04	1.08	0.37	1.23	0.52	1.30	0.28
CLA (C18:2 c9, t11)	0.36^{a}	0.75^{c}	0.73^{b,c}	0.54^{a,b}	0.002	0.05	0.78	0.36	–	–	0.72	0.31
Total SFA	56.50	61.90	61.90	62.90	0.080	1.59	44.20	43.40	42.40	39.40	40.40	37.50
Total MUFA	40.90	36.40	36.50	34.70	0.080	1.47	38.50	45.30	42.10	38.20	39.20	43.30
Total PUFA	2.62^{a}	1.69^{b}	1.60^{b}	2.42^{a}	0.003	0.15	6.09	4.50	6.65	12.90	8.67	9.62

CLA: conjugated linoleic acid, G: Group, MUFA: monounsaturated fatty acid, PUFA: polyunsaturated fatty acid, SE: standard error, SFA: saturated fatty acid

* G1: Young, grain-finished beef; G2: Young, grass-finished beef; G3: Older, grass-finished beef; G4: Old, culled cows, traditionally from grass, finished off on a grain-based feeding system

–: Not detected during analyses

a, b, c: The mean values in a column with different superscripts differed significantly in fatty acid content between the different production groups (p-value ≤ 0.050)

acid in all groups (> 20%). Variations between countries were also evident. Stearic acid values were reported in studies in the USA, UK and Argentina of between 10% and 14% in grain-fed beef, and 13% and 17% in grass-fed beef, compared with 20% and 23% in South African grain- and grass-fed beef, respectively (Table I).

Monounsaturated fatty acids

Monounsaturated fatty acids (MUFAs), palmitoleic acid (C16:1 n-7) and oleic acid (C18:1 n-9) have shown to decrease total and LDL cholesterol in humans.[27] More than 25% of fatty acid in South African beef is oleic acid (C18:1 n-9) (Table I). Although no significant difference was found between the different groups in this regard, group 1 (young, grain-finished beef) contained a slightly higher percentage of oleic acid than that in the other groups on a grass-based feeding system (Table I). Internationally, beef from grain-based feeding systems in the USA and Argentina contained a slightly higher proportion of MUFA, similar to what was observed in the current study. This tendency was reversed in the UK. Although they were prevalent in smaller quantities, heptadecenoic (C17:1) and eicosenoic acid (C20:1 n-11) differed significantly between the production groups.

Polyunsaturated fatty acids

Polyunsaturated fatty acids (PUFAs) are commonly known as beneficial fatty acids, and lower total and LDL cholesterol. Certain PUFAs exhibit anti-cancer properties, anti-inflammatory responses and other cardiovascular benefits. Omega-3 (n-3) and omega-6 (n-3) PUFAs are required in the diet of humans as they cannot be synthesised within the human body, and function as the carriers of fat-soluble vitamins. They also play an integral role in the immune system.[28]

It was found in the current research study that beef produced from cattle finished on a grain diet (groups 1 and 4) contained a statistically significant higher proportion of PUFA than that in grass-fed cattle (p-value 0.005) (Table I). The majority of the PUFAs were linoleic acid (C18:2 n-6). This finding is similar to those in studies in the UK[29] and Argentina[30] in which more n-6 fatty acid in the beef from grain- than grass-fed cattle (Table I) was notably reported, i.e. 2-3 times. The concentration of n-3 fatty acid, and specifically alpha-linolenic acid (C18:3 n-3), was found to be significantly higher in the two groups on a grass-based feeding system, than in the groups finished on grain (p-value < 0.001). This higher ratio of n-3 fatty acid in beef from grass-fed cattle has been recorded internationally.[29-31] The differences in n-3 and n-6 fatty acid quantities found in the beef from grass- versus grain-fed cattle also had a notable impact on the n-6:n-3 ratio of the meat (Table II).

Research has shown significantly more omega fatty acid in phospholipids, an essential component of the cell membranes of muscles, and a declining proportion of phospholipids to total fat, as total fat in the carcass increases. What this means is that the higher the intermuscular and subcutaneous fat content of the beef,

Table II: Total fat and fatty acid composition of trimmed and untrimmed portions of South African beef produced on different production systems*

Fat or fatty acids	Untrimmed cooked portion						Trimmed of subcutaneous fat						Trimmed of subcutaneous and intermuscular fat					
	G1	G2	G3	G4	p-value	SE	G1	G2	G3	G4	p-value	SE	G1	G2	G3	G4	p-value	SE
Total fat (g)	17.46	20.41	20.60	21.56	0.059	0.91	14.46^{a}	16.29^{a,b}	19.63^{a,b}	19.66^{b}	0.019	0.90	6.96^{a}	9.77^{b}	10.26^{b}	10.44^{b}	0.007	0.55
Lauric (C120)	0.01^{a}	0.01^{a,b}	0.01^{b}	0.00^{a}	0.025	0.00	0.00^{a}	0.01^{a,b}	0.01^{b}	0.00^{a}	0.018	0.00	0.00^{a}	0.00^{b}	0.00^{b}	0.00^{a}	< 0.001	0.00
Myristic (C14:0)	0.34	0.42	0.51	0.40	0.232	0.05	0.28	0.34	0.43	0.37	0.133	0.04	0.14^{a}	0.20^{b}	0.2^{b}	0.19^{a,b}	< 0.001	0.01
Myristoleic (C14:1 n-9)	0.04^{a}	0.05^{a,b}	0.07^{b}	0.04^{a}	0.040	0.01	0.03^{a}	0.04^{a,b}	0.06^{b}	0.04^{a}	0.035	0.01	0.02^{a}	0.02^{a}	0.04^{b}	0.02^{a}	0.004	0.00
Pentadecylic (C15:0)	0.06^{a}	0.11^{b}	0.11^{b}	0.05^{a}	0.006	0.01	0.05^{a}	0.09^{b}	0.09^{b}	0.04^{a}	0.008	0.01	0.02^{a}	0.05^{b}	0.05^{b}	0.02^{a}	< 0.001	0.00
Palmitic (C16:0)	2.60	3.43	3.75	3.33	0.160	0.32	2.15	2.74	3.19	3.03	0.075	0.25	1.04^{a}	1.64^{b}	1.83^{b}	1.61^{b}	0.002	0.09
Palmitoleic (C16:1 n-7)	0.21	0.27	0.39	0.27	0.060	0.04	0.17^{a}	0.21^{a,b}	0.33^{b}	0.24^{a,b}	0.034	0.03	0.08^{a}	0.13^{a}	0.19^{b}	0.13^{a}	0.003	0.01
Margaric (C17:0)	0.15	0.18	0.18	0.12	0.080	0.02	0.12	0.14	0.15	0.11	0.173	0.01	0.06^{a}	0.09^{b}	0.09^{b}	0.06^{a}	0.008	0.01
Stearic acid (C18:0)	2.13	2.67	2.62	2.74	0.270	0.22	1.76	2.14	2.23	2.49	0.111	0.18	0.86^{a}	1.28^{b}	1.27^{b}	1.32^{b}	0.010	0.08
Elaidic (C18:1)	0.04^{a}	0.03^{b}	0.02^{b}	0.03^{a,b}	0.020	0.00	0.03^{a}	0.02^{a,b}	0.02^{b}	0.03^{a,b}	0.040	0.00	0.02	0.01	0.01	0.01	0.208	0.00
Oleic (C18:1 n-9)	3.12	3.60	3.81	3.51	0.650	0.39	2.58	2.89	3.25	3.20	0.485	0.33	1.24	1.72	1.88	1.70	0.104	0.16
Vaccenic (C18:1 n-7)	0.24	0.17	0.11	0.14	0.080	0.03	0.20	0.14	0.10	0.13	0.141	0.03	0.10	0.08	0.06	0.07	0.430	0.02
Linoleic (C18:2 n-6)	0.21^{a}	0.04^{b}	0.05^{b}	0.13^{a,b}	0.010	0.03	0.17^{a}	0.03^{b}	0.04^{b}	0.12^{a,b}	0.008	0.02	0.08^{a}	0.02^{b}	0.02^{b}	0.06^{a,b}	0.019	0.01
Arachidic (C20:0)	0.01^{a}	0.07^{b}	0.07^{b}	0.03^{a}	0.002	0.01	0.01^{a}	0.05^{b}	0.06^{b}	0.03^{a}	0.003	0.01	0.01^{a}	0.03^{b}	0.03^{b}	0.01^{a}	< 0.001	0.00
Eicosenoic (C20:1 n-11)	0.01	0.01	0.01	0.01	0.930	0.00	0.01	0.01	0.01	0.01	0.95	0.00	0.00	0.00	0.00	0.00	1.000	0.00
CLA (C18:2 c9, t11)	0.02^{a}	0.06^{b}	0.06^{b}	0.04^{a,b}	0.010	0.01	0.02^{a}	0.05^{b}	0.05^{b}	0.04^{b}	0.005	0.01	0.01^{a}	0.04^{c}	0.03^{c}	0.02^{b}	< 0.001	0.00
α-linolenic (C18:3 n-3)	0.01^{a}	0.05^{b}	0.05^{b}	0.02^{a}	0.001	0.01	0.01^{a}	0.04^{b}	0.04^{b}	0.02^{a}	0.002	0.00	0.00^{a}	0.02^{b}	0.02^{b}	0.01^{a}	< 0.001	0.00
Total SFA	5.31	6.88	7.24	6.66	0.200	0.61	4.39	5.51	6.16	6.07	0.103	0.48	2.16^{a}	3.30^{b}	3.52^{b}	3.22^{b}	0.003	0.18
Total MUFA	3.66	4.12	4.42	3.99	0.670	0.43	3.02	3.31	3.77	3.65	0.518	0.37	1.45	1.97	2.18	1.94	0.110	0.18
Total PUFA	0.23	0.15	0.16	0.19	0.200	0.03	0.19	0.12	0.14	0.18	0.173	0.02	0.09	0.07	0.08	0.09	0.474	0.01
Total n-6	0.23	0.10	0.11	0.17	0.050	0.03	0.19	0.08	0.10	0.16	0.055	0.03	0.09	0.05	0.05	0.08	0.134	0.01
Total n-3	0.01^{a}	0.05^{b}	0.05^{b}	0.02^{a}	0.005	0.01	0.01^{a}	0.04^{b}	0.04^{b}	0.02^{a}	0.002	0.00	0.00^{a}	0.02^{b}	0.02^{b}	0.01^{a}	< 0.001	0.00
n-6:n-3 ratio	23.00: 1.00	2.00: 1.00	2.20: 1.00	8.50: 1.00	–	–	19.00: 1.00	2.00: 1.00	2.50: 100	8.00: 1.00	–	–	22.50: 1.00	2.50: 1.00	2.50: 1.00	8.00: 1.00	–	–

CLA: conjugated linoleic acid, G: Group, MUFA: monounsaturated fatty acid, n-3: omega-3, n-6: omega-6, PUFA: polyunsaturated fatty acid, SE: standard error, SFA: saturated fatty acid

* G1: Young, grain-finished beef; G2: Young, grass-finished beef; G3: Older, grass-finished beef; G4: Old, culled cows, traditionally from grass, finished off on a grain-based feeding system

–: Not detected during analyses

a, b: The mean values in a column with different superscripts differed significantly in fatty acid content between the different production groups (p-value ≤ 0.050)

the lower the proportion of PUFA to total fat. Although the amount of subcutaneous fat was not reported in the current study, the assumption was that as beef from grain-finished cattle contained a significantly higher proportion of PUFA (Table I), the beef from grain-finished cattle possibly contained less subcutaneous fat than intramuscular fat.

Fatty acid composition per edible portion and the effect of trimming

Total fat content

As a result of lean produce becoming increasingly popular, the average total fat content of South African beef has decreased over time from 22% fat per edible portion in the 1970s to less than 12% in 2014.[32] The majority of beef produced in South Africa falls within group 1 of the current study, and interestingly, beef from this grain-fed group also contained the least amount of fat per edible portion (Table II), as well as the lowest intermuscular fat percentage of all the production groups.[32] This is in direct contrast with the findings from a review of four studies on the composition of beef in the USA, in which it was found that grass or forage feeding significantly lowered the total fat content of the beef.[8,17] This finding was probably owing to the previously mentioned notable differences between the South African production and classification (grading) systems for beef and those in other countries.

When untrimmed, a statistically significant difference in total fat content (g/100 g) between beef produced on the different production systems was not found. The fat content ranged from 17-22 g per 100 g. When trimmed of the subcutaneous (outside) fat cover after cooking, the fat content increased significantly in accordance with the animal's age (p-value 0.019). Significantly more fat was found in the beef from culled, grain-finished animals in group 4 than that in the beef from young, grain-finished animals in group 1. When trimmed of all visible fat, i.e. trimmed of subcutaneous and intermuscular fat, with only marbling or intramuscular fat remaining, the beef from young animals from feedlots (grain fed) contained significantly less fat (p-value 0.007) than that from the other production groups. Translated to human consumption, a 100 g portion of trimmed beef from young feedlot animals contained 3-4 g less total fat per 100 g than the beef obtained from a grass- or forage-based feeding system (Table II).

Saturated fatty acids

When evaluating the fatty acid composition of edible portions, a statistically significant difference was not seen for either total SFA, MUFA or PUFA between the untrimmed portions from different production systems. However, when the fat was fully trimmed, significant differences were noted. Total fat content was lower, and the total SFA content was significantly lower in the beef from fully trimmed, young, grain-fed animals from group 1 (p-value 0.003), compared to animals from the other groups.

Untrimmed, the SFAs [lauric acid (C12:0), pentadecydic acid (C15:0) and arachidic acid (C20:0)] were significantly less in group 1 and 4, i.e. the groups finished off on a grain-based diet. When fully trimmed of all visible fat, the beef from young, grain-fed animals from group 1 contained significantly less stearic acid (C18:0) and palmitic acid (C16:0) than that in all of the other groups, and less lauric (C12:0), myristic (C14:0), pentadecyclic (C15:0) and arachidic acid (C20:0) than that in the two exclusively grass-fed groups, i.e. group 2 and 3 (Table II). When fully trimmed of all fat, a 100 g serving of South African beef from a grain-based feeding system delivered at least 1 g less SFA than the same serving of beef from a grass-fed animal. A high intake of SFA has been associated with raised LDL cholesterol in humans, while replacing SFA with PUFA is reported to decrease the risk of coronary heart disease.[4] Thus, dietary recommendations include limiting the consumption of SFA to ≤ 10% of total dietary energy.[4]

Monounsaturated fatty acids

Beef is known to be a primary source of MUFA in a Western diet. The most common source thereof is oleic acid (C18:1 n-9). It was found in the USA that oleic acid increased in the beef as the marbling differentiated, and that the beef from animals that were grass fed in the USA contained 30-70% less MUFA than beef with a higher degree of marbling in an animal who was grain fed.[17] A statistically significant difference was not noted with regard to the MUFA content between the different productions systems in South Africa (Table II). This finding was most probably owing to the fact that the South African classification system does not promote marbling. Young, target-grade beef is produced as leanly as possible, and thus contains less (although not statistically significant) MUFA than the slightly fattier beef from grass-fed animals (Table II).

In the context of dietary recommendations, it was predicted following research in the USA that increasing the consumption of beef from grass-fed animals in favour of beef from grain-fed animals could negatively impact upon the MUFA:SFA ratio.[17] This, in turn, could lower plasma high-density lipoprotein cholesterol, increase triglycerides and increase LDL cholesterol. As no statistically significant difference was seen between the MUFA content of the beef from South African grass- versus grain-fed animals, the same hypothesis cannot be made with regard to South African produce.

Omega-6 and omega-3 polyunsaturated fatty acids

The PUFA content of beef is relatively low, averaging up to 5% of total fatty acids.[17] Daley et al[8] found that PUFA in USA beef increased by as much as 25% in response to grass feeding. However, with the lower total fat content of beef from grass-fed cattle in the USA, the total amount of PUFA consumed from an edible portion of beef from grass-fed cattle may in fact be lower than that consumed from beef from grain-fed cattle. In South Africa, little difference is seen in the total fat and total PUFA content of untrimmed beef produced on the difference production systems (Table II). However, noteworthy statistically significant differences were seen between the individual PUFAs, particularly in relation to n-6 and n-3 fatty acids.

The n-6 fatty acid, linoleic acid (C18:2 n-6), is the primary PUFA found in beef. Linoleic acid (C18:2 n-6) in South African untrimmed beef was significantly more prevalent in grain-finished produce, whereas alpha-linolenic acid (C18:3 n-3) was found to be significantly higher in the red meat from grass-finished animals (groups 2 and 3). The finding is similar to that identified by Warren et al,[33] who reported that n-3 fatty acids (C18:3 n-3) in the beef muscle from cattle finished on a grass silage-based diet were higher than those in the beef muscle from cattle finished on a grain-based diet, and that n-6 fatty acids (C18:2 n-6) were higher in the beef muscle from cattle finished on a grain-based concentrated diet than in the beef muscle from cattle fed a grass silage diet. This finding was not influenced by trimming (Table II).

It has been recommended that a healthy diet should consist of up to four times more n-6, than n-3, fatty acids, yet the majority of Western diets contain between 10 and 30 times more n-6 than n-3 fatty acids.[8] This scenario has been associated with the rise in inflammatory disorders in many Westernised populations.[7] The beef from young, grain-fed cattle in South Africa contains approximately 20 times more n-6 than n-3 fatty acids, whereas the beef from grass-fed cattle contains only twice as much n-6 as n-3 fatty acids, attributed to the generally high concentration of n-3 fatty acids (specifically alpha-linolenic acid) in beef from grass-fed cattle. This favourable relationship needs to be further investigated. The quantities present per edible portion should be noted before dietary recommendations can be made.

Conjugated linoleic acid

While nonconjugated trans-fatty acids derived from partially hydrogenated vegetable oils may adversely influence human health, research has found that conjugated trans-fatty acids produced by ruminant animals (mainly CLA) may benefit human health.[33] CLA consists of a grouping of isomers of linoleic acid (C18:2 n-6), and is predominantly found in the milk and meat of ruminant animals, formulated through a microbial process in the rumen. The reported values for CLA concentrations in raw beef were found to be between 1.2 and 10.0 mg/g fat following a review on the CLA content of meat and meat products, and these significantly varied between the countries, production systems and cuts of carcass.[17,34,35]

The CLA in South African beef was significantly higher (p-value < 0.050) in the beef from cattle who spent the majority of their lives consuming grass (groups 2, 3 and 4) than in the beef from cattle finished on grains (group 1), irrespective of the degree of trimming (Table II). A higher CLA content has also been associated with higher intramuscular fat content, which explains why CLA content only decreases somewhat with the trimming of visible fat.

Optimal dietary intake levels for CLA still need to be established. It was reported that an intake of 3.5 g CLA per day was needed to elicit human health benefits in the 1980s following studies on rats, while it was recommended after studies in the 1990s that only 95 mg CLA per day would be sufficient to demonstrate a positive effect in the reduction of breast cancer.[36] In 2001, researchers reported values of 620 mg/day for men and 441 mg/day for women, which could have an anticarcinogenic effect.[37] South African beef contains between 10 mg and 60 mg of CLA per 100 g portion, depending on the production system used and the degree of trimming (Table II). Untrimmed beef from grass-fed cattle provides the highest quantity of beneficial CLA per edible portion, at 60 mg per 100 g cooked portion.

Conclusion

The results of this study have revealed that the fatty acid composition of South African beef is exceptional, and found only in this country. Although a statistically significant difference in the total fat content (g/100 g edible portion) between beef produced on the different production systems was not found, beef from young animals fed on a grain-based diet contained less total fat than the beef from their grass-finished counterparts. The trimming of fat notably influenced the total fat. When trimmed of all visible fat, meat from young feedlot animals contained between 3 g and 4 g less total fat per 100 g portion than meat from grass-fed cattle. A 100 g serving of beef from grain-finished cattle also contained at least 1g less SFA than the same serving of beef from grass-fed cattle.

Dietary recommendations state that up to four times more n-6, than n-3, fatty acids, should be consumed. Beef from young, grain-fed cattle contains approximately 20 times more n-6 fatty acid [linoleic acid (C18:2 n-3)] than n-3 fatty acid [alpha-linolenic acid (C18:3 n-3)], whereas beef from grass-fed cattle contains only twice as much n-6, as n-3, fatty acids. This favourable relationship of n-6 to n-3 fatty acid in grass-fed beef should be further explored. However, the quantities of n-6 to n-3 fatty acid present per edible portion should also be determined.

South African beef contains between 10 mg and 60 mg beneficial CLA per 100 g edible portion. The highest quantity of CLA is found in untrimmed beef from grass-fed cattle. It has been reported in studies, although inconclusive, that only 95 mg CLA per day could have a positive effect on human health.

Declaration

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