HOW HEALTHY IS ZEBRA MEAT?

INTRODUCTION

Zebra are almost completely grazers that manage to survive on lower quality forage. Zebra furthermore consume the older grass growth ahead of the other grazing species, so as to enable the selective grazing by other grazers (Hack *et al.,* 2002). South Africa regularly harvests zebra for export. In 2011, the meat from 745 carcasses was exported. These were all harvested during the winter months. Since zebra are classified as equine and not as cloven hoofed animals, they do not fall under the regulations that apply to foot-and-mouth disease controls. Consequently, the industry can export zebra meat when there are outbreaks of this disease. The meat from zebra is also sought after for the making of salami, in addition to the high value of the zebra skin (33 – 37% of the total value) (van Schalkwyk, 2010). Although the meat is exported and consumed locally, little information exists on the meat composition of zebra. This report discusses the meat composition of zebra harvested for export.

MATERIALS AND METHODS

Harvesting

Twenty zebra were harvested from the northern Bushveld, Limpopo Province, South Africa. Harvesting was in the middle of winter (July) in a summer rainfall region.

Sample preparation

After skinning, the *Longissimus dorsi* muscle and subcutaneous fat layer of each zebra carcass (Mean weight = 138.2 kg; Standard Deviation (SD) = 23.50; Minimum (Min) = 106.0 kg; Maximum (Max) = 190.6 kg) was removed from the last rib to the caudal end of the *longissimus* muscle. The muscles samples were vacuum packed and frozen until analysed.

The frozen vacuum packed muscle samples were removed from the freezer 24 h prior to processing and thawed at ± 4˚C. The subcutaneous fat was removed from the thawed samples prior to homogenising the muscle. Both the muscle and subcutaneous fat were individually vacuum packed and frozen at -18˚C until chemical analyses. Prior to chemical analyses, the frozen, homogenised fat and muscle samples were removed from the freezer and thawed at ± 4˚C for 24 h.

Proximate analysis

Moisture content

The moisture contents (% wet weight) of 2.5 g homogenised meat samples were determined for all samples in duplicate by drying for 24 h at 100°C as described in the official method of the Association of Official Analytical Chemists (AOAC, 2002a).

Total protein content

The total crude protein content (% wet weight) of the defatted, dried and ground meat samples was analysed in duplicate by means of the Dumas combustion method 992.15 (AOAC, 2002b). The samples (0.1 g) were encapsulated in a Leco™ foil sheet and analysed in a Leco Nitrogen/Protein Analyser (FP – 528, Leco Corporation). The Leco analyser was calibrated with ethylene-diamine-tetra-acetic acid (EDTA) before each batch of samples were analysed. A calibration sample of known protein content was run after every 10 samples in order to ensure the accuracy and recovery rate of the method. The results were obtained as percentage nitrogen (N), which was then converted to total crude protein (%) by multiplying the nitrogen value with a conversion factor of 6.25. The latter was then converted to percentage protein per gram of meat sample by using the following formula:

$$\% \text{ protein} = \% \text{ crude protein} \times (100 - \% \text{ moisture} - \% \text{ fat}) / 100$$

Total lipid content

The total lipid content (% wet weight) of 5 g homogenised meat samples was determined in duplicate using the chloroform/methanol extraction gravimetric method described by Lee *et al.* (1996). A chloroform/methanol solution concentration of 1:2 (v/v) was used where the samples were expected to contain less than 5% fat.

Ash content

The ash content (% wet weight) of the moisture free samples was determined in duplicate using the official AOAC method 942.05 by ashing the samples for 6 h at 500˚C (AOAC, 2002c).

Fatty acid analysis

After thawing, the fat from a 2 g sample was extracted with a chloroform:methanol (2:1; v/v) solution according to the method of Folch *et al*. (1957). All the extraction solvents contained 0.01% butylated hydroxytoluene (BHT) as an antioxidant. A polytron mixer (WiggenHauser Homogeniser, D-500 fitted with a standard shaft 1; speed setting D) was used to homogenise the sample with the extraction solvent. Heptadecanoic acid (C17:0) was used as an internal standard (catalogue number H3500, Sigma–Aldrich Inc., 3050 Spruce Street, St. Louis, MO 63103, USA) to quantify the individual fatty acids. Of the extracted lipids, 250 µL was transmethylated for 2 h at 70°C with 2 mL of a methanol/sulphuric acid (19:1; v/v) solution as transmethylating agent. After cooling to room temperature, the resulting fatty acid methyl esters (FAMEs) were extracted with water and hexane. The top hexane phase was transferred to a spotting tube and dried under nitrogen. Fifty µL hexane was added to the dried sample of which 1 µL was injected.

The FAME were analysed using a Thermo Finnigan Focus gas-chromatograph (Thermo Electron S.p.A, Strada Rivoltana, 20090 Rodana, Milan, Italy) equipped with a flame ionisation detector, using a 60 m BPX70 capillary column with an internal diameter of 0.25 mm and 0.25 µm film (SGE International Pty Ltd, 7 Argent Place, Ringwood, Victoria 3134, Australia) with a run time

of approximately 45 min. The temperature programme was linear at 7°C·min^{-1} with the temperature settings as follows: initial temperature of 60°C (5 min) and the final temperature at 160°C, an injector temperature of 220°C and a detector temperature of 260°C. The gas flow rate of the hydrogen carrier gas was 30 ml min^{-1}. The FAME of the samples were identified by comparing the values with the retention times of a standard FAME mixture (Supelco™ 37 Component FAME mix, 10 mg.min^{-1} in CH2Cl2, Cat no. 47885-U. Supelco™, North Harrison Rd, Bellefonte, PA 16823-0048, USA). Values were recorded as % of total fatty acids in each meat sample.

RESULTS

Proximate composition

The proximate composition (%) of the meat from 20 zebra harvested from the same region and season is presented in Table 1.

Table 1 The proximate composition (%) of zebra (n = 20) *Longissiums dorsi* muscle

	Mean	SD	Min	Max
Moisture	76.4	0.77	74.4	77.9
Protein	22.3	0.50	21.4	23.3
Fat	1.5	0.47	1.0	3.1
Ash	1.1	0.07	1.0	1.3

SD, Standard Deviation; Min, Minimum; Max, Maximum

Fatty acid profile

A large proportion of the zebra carcasses had yellow subcutaneous fat although the fat levels were not very thick since the animals were harvested in winter (low plane of nutrition). The fatty acid profile (% of fatty acids present) of the *Longissimus dorsi* muscle and subcutaneous fat of zebra is presented in Table 2. The 18-carbon fatty acids were dominant with the muscle having a mean C18:0 (stearic acid) content of 14.0%, C18:1ω9c of 16.7% and a C18:2ω6c of 23.3%. Both the intramuscular and the subcutaneous fat had high levels of C18:3ω6 (gamma-linoleic acid). Zebra has similar saturated fatty acid (SFA) and polyunsaturated fatty acid (PUFA) concentrations (≈40% of each) in the intramuscular fat of the *Longissimus dorsi* muscle and the subcutaneous fat, resulting in a polyunsaturated to saturated fatty acid ratio (PUFA:SFA) of ≈1.0. The omega-6 to omega-3 fatty acid ratio (ω6:ω3) of the *Longissimus dorsi* muscle was much lower (13.9) than that of the subcutaneous fat (177.6). The high ω6:ω3 value of the latter being due to the very low levels of ω3 PUFA (1.1%) present in zebra subcutaneous fat (Table 2). Zebra meat has a calculated mean atherogenic index of 0.5 (SD 0.23; Min 0.2; Max 1.3), a thrombogenic index of 1.0 (SD 0.42; Min 0.4; Max 2.5) and a hypocholesterolaemic/hypercholesterolaemic fatty acid ratio of 35.9 (SD 21.33; Min 7.8; Max 76.7).

Table 2 The fatty acid profile (% of fatty acids present) of the *Longissimus dorsi* muscle and subcutaneous fat of zebra (n = 20)

	Longissimus dorsi muscle				Subcutaneous fat			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
C12:0	0.0	0.00	0.0	0.0	0.0	0.07	0.0	0.2
C14:0	0.8	0.27	0.3	1.4	1.0	0.72	0.0	3.0
C15:0	0.2	0.04	0.1	0.3	0.2	0.15	0.0	0.5
C16:0	24.3	1.51	21.6	27.7	25.9	8.89	11.0	51.7
C18:0	14.0	2.44	7.8	18.9	7.6	6.48	1.5	24.7
C20:0	0.6	0.11	0.4	0.8	0.4	0.29	0.1	1.2
C21:0	0.0	0.00	0.0	0.0	0.0	0.02	0.0	0.1
C22:0	1.5	0.59	0.4	3.1	0.4	0.97	0.0	3.9
C24:0	0.0	0.00	0.0	0.0	0.0	0.00	0.0	0.0
C14:1	0.0	0.00	0.0	0.0	0.1	0.09	0.0	0.4
C15:1	0.0	0.00	0.0	0.0	0.1	0.04	0.0	0.2
C16:1	1.6	0.68	0.0	3.4	1.8	1.17	0.5	4.3
C18:1ω9c	16.7	4.71	10.4	31.0	24.6	9.46	7.9	48.2
C18:1ω9t	0.2	0.05	0.1	0.3	0.2	0.14	0.0	0.5
C20:1	0.1	0.03	0.1	0.2	0.1	0.15	0.0	0.5
C22:1ω9	0.2	0.12	0.0	0.5	0.4	0.95	0.0	4.2
C24:1	0.0	0.00	0.0	0.0	0.0	0.00	0.0	0.0
C18:2ω6c	23.3	4.35	12.0	29.5	9.8	6.32	1.8	24.4
C18:2ω6t	0.2	0.07	0.1	0.4	0.1	0.11	0.0	0.4
C18:3ω3	0.3	0.04	0.2	0.3	0.2	0.21	0.1	0.8
C18:3ω6	12.3	4.36	4.7	20.3	25.6	16.25	4.7	66.9
C20:2	0.4	0.08	0.2	0.7	0.2	0.22	0.0	1.0
C20:3ω6	0.6	0.12	0.5	0.9	0.3	0.26	0.0	0.9
C20:3ω3	1.4	0.64	0.5	3.3	0.4	0.97	0.0	4.3
C20:4ω6	0.0	0.00	0.0	0.0	0.1	0.20	0.0	0.7
C20:5ω3	0.0	0.00	0.0	0.0	0.0	0.00	0.0	0.0
C22:2	0.0	0.00	0.0	0.0	0.0	0.00	0.0	0.0
C22:5ω3	0.7	0.34	0.2	1.6	0.3	0.67	0.0	2.4
C22:6ω3	0.6	0.25	0.2	1.2	0.2	0.47	0.0	1.6
SFA	41.4	3.25	34.1	46.6	35.5	8.41	16.4	56.0
MUFA	18.6	5.14	11.8	34.5	27.0	9.17	9.1	48.9
PUFA	39.6	3.19	31.1	45.6	37.2	14.03	14.0	73.0
ω3 PUFA	2.97	1.16	1.18	5.99	1.12	2.17	0.08	8.69
ω6 PUFA	36.21	3.06	29.71	42.58	35.89	14.28	13.82	72.74
PUFA:SFA	1.0	0.09	0.8	1.2	1.2	0.97	0.3	4.4
ω6:ω3	13.9	5.01	5.8	25.2	177.6	159.04	3.5	489.4

SD, Standard Deviation; Min, Minimum; Max, Maximum; ND, Not Detected; SFA, total Saturated Fatty Acids; MUFA, total Monounsaturated Fatty Acids; PUFA, total Polyunsaturated Fatty Acids; ω3 PUFA, total Omega-3 Polyunsaturated Fatty Acids; ω6 PUFA, total Omega-6 Polyunsaturated Fatty Acids; PUFA:SFA, Polyunsaturated to Saturated Fatty Acids Ratio; ω6:ω3, Omega-6 to Omega-3 Polyunsaturated Fatty Acids Ratio
SFA = sum of C14:0, C15:0, C16:0, C18:0, C20:0, C21:0 and C22:0; MUFA = sum of C14:1, C15:1, C16:1ω9, C18:1ω9c, C18:1ω9t, C20:1ω9, C22:1ω9 and C24:1ω9; PUFA = sum of C18:2ω6c, C18:2ω6t, C18:3ω3, C18:3ω6, C20:2, C20:3ω3, C20:3ω6, C20:4ω6, C20:5ω3, C22:2, C22:5ω3 and C22:6ω3; ω3 PUFA = sum of C18:3ω3, C20:3ω3, C20:5ω3, C22:5ω3 and C22:6ω3; ω6 PUFA = sum of C18:2ω6c, C18:3ω6, C20:3ω6 and C20:4ω6; PUFA:SFA = [(sum of C18:2ω6c, C18:2ω6t, C18:3ω3, C18:3ω6, C20:2, C20:3ω3, C20:3ω6, C20:4ω6, C20:5ω3, C22:2, C22:5ω3 and C22:6ω3)/(sum of C14:0, C15:0, C16:0, C18:0, C20:0, C21:0 and C22:0)]; ω6:ω3 = [(sum of C18:2ω6c, C18:3ω6, C20:3ω6 and C20:4ω6)/(sum of C18:3ω3, C20:3ω3, C20:5ω3, C22:5ω3 and C22:6ω3)]

DISCUSSION

Proximate composition

Meat generally consists of ~75% moisture, ~19% protein, ~2.5% fat and smaller quantities of other components (Lawrie & Ledward, 2006). Zebra meat can be classified as a protein dense foodstuff due to its high protein content (22.3%). Additionally, the meat from zebra has a low mean total fat content with a minimum of 1.0% and a maximum of 3.1%. Zebra meat with a mean total intramuscular fat content of 1.5% (as indicated in Table 1) can be marketed as being low in fat, since the mean fat content in the meat is less than 3% (Anon., 2010). Onyango *et al.* (1998) reported more or less similar proximate composition values for zebra loin muscles at 75.2% moisture content, 22.8% crude protein content, 0.3% crude fat content and 1.5% ash content. Zebra meat is therefore high in protein and low in fat.

Horses are hind-gut fermenters similar to zebra. The mean moisture and protein contents of horse meat is lower (72.6% and 19.8%, respectively), the fat content much higher (6.6%) and the ash content is similar to that in zebra meat (Badiani *et al.,* 1997). The latter differences in proximate composition of the meat from zebra compared to horse could be attributed to the differences in the diets of these species.

Fatty acid profile

Zebra are grazing animals. The fatty acid contents of grass is quite low (Khan *et al.,* 2012), nonetheless the primary fatty acid present is C18:3ω3 (alpha-linolenic acid, ALA) and smaller quantities of C18:2ω6 (linoleic acid) and C16:0 (palmitic acid) (McDonald *et al*., 2002; Khan *et al.,* 2012). Since zebra are not ruminants, it is expected that the fatty acid profile in the meat will more or less be a representation of the composition of the fatty acids in the diet. The loin muscle and subcutaneous fat of zebra both have high palmitic acid contents (24.3% and 25.9%, respectively) and very low ALA contents (0.3% and 0.2%, respectively). The linoleic acid content was higher in the loin muscle (23.3%) in comparison with the 9.8% of linoleic acid in the subcutaneous fat.

The low ALA contents in zebra meat is not yet well understood, since they are primarily grazers and grass mainly contain ALA. However, the low ω3 PUFA content in the zebra meat might be due to the incorporation of the ω3 PUFA in other parts of the body. Additionally, red meat usually has low quantities of ω3 PUFA (Warriss, 2000).

The four fatty acids present at the greatest quantities in zebra meat were palmitic acid, stearic acid (C18:0) (both SFA), C18:1ω9 (oleic acid, a MUFA) and linoleic acid (a PUFA) (Table 2). The latter was similarly found in the meat from farmed venison (except for linoleic acid) (Aidoo & Haworth, 1995) as well as in the meat from young Tudanca bulls (Humada *et al.,* 2012).

In comparison with the SFA, MUFA and PUFA contents in horse meat (34.8%, 46.5%, and 18.6% of total fatty acids, respectively) (Badiani *et al.,* 1997), zebra meat has somewhat higher SFA (41.1%), slightly lower MUFA (18.6%) and more than double the PUFA contents (39.6%) (Table 2). Some researchers suggest a P:S of ≥0.70 and ω6:ω3 of ≤5.0 for red meat to be seen as healthy for human consumption (Raes *et al*., 2004). Therefore, the loin muscle and subcutaneous fat of zebra both had favourable mean PUFA:SFA values, but unfavourable ω6:ω3 values.

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