MINERAL DISTRIBUTION IN THE MUSCLES OF FREE-RANGING RUMINANTS

Jeannine Neethling[1,2*], Louwrens C. Hoffman[1] and Trevor J. Britz[2]

[1] Department of Animal Sciences, Faculty of Agriculture, Stellenbosch University, Stellenbosch, South Africa

[2] Department of Food Science, Faculty of Agriculture, Stellenbosch University, Stellenbosch, South Africa

Abstract – The mineral composition and profile of six commercially important blesbok (*Damaliscus pygargus phillipsi*) muscles was investigated in this study. Blesbok are grazing, free-ranging ruminants. The mineral composition in the forage consumed is influenced by the soil and in turn influences the mineral composition in blesbok meat. However, muscle type had a significant influence on the mineral composition of blesbok meat. The mineral profile of the LD (loin) and hindquarter (*Biceps femoris, Semimembranosus* and *Semitendinosus*) muscles differed significantly from the forequarter muscles (*Infraspinatus* and *Supraspinatus*). The latter thus proposes that the mineral composition of the LD muscles from free-ranging ruminant species might not be a representation of the content in the other skeletal muscles, as is believed with domesticated livestock species. Since meat is a major source of minerals in human diets, these differences can influence the labelling of different muscles/meat cuts from free-ranging ruminant species, therefore emphasizing that this field of study warrants further research.

Key Words – Blesbok, Minerals, Muscle Variation

I. INTRODUCTION

Meat supplies a large variety of essential minerals for normal growth, reproduction and health in humans. However, the essential mineral requirements of free-ranging animals are generally met by natural grazing and/or browsing [1]. Soil is a major source of minerals for plant growth [2] and consequently forage is the intermediary step for the transport of minerals from the ground (soil) to the animals [1]. The essential mineral concentrations within forage may, however, vary with differences in the plant species, growth stage (maturity), soil type, yield, climate and cultivation conditions [3].

Minerals have very specific functions in the body of humans and animals; such as to maintain physiological equilibrium as well as generally acting as co-factors or activators of enzyme systems [1]. Macro minerals such as calcium, phosphorus and magnesium are important in the skeleton [1, 3], whereas iron is essential in oxygen transport, as part of the haemoglobin molecule [1, 3]. Iron is the mineral element with an essential role in almost all living processes, while calcium is generally the most prevalent mineral element in the bodies of humans and animals [1, 3]. Even though calcium is mainly present in the skeleton and teeth, roughly 1% of the total body calcium has essential functions in the majority of living cells and tissue fluids [1]. Moreover, calcium is essential for maintaining normal function of the hart and skeletal muscles as well as having an important role during the coagulation of blood [1, 3]. Magnesium acts as an activator for a number of enzyme systems, especially those related to the transport of nerve impulses (for e.g. adenosine phosphatase) as well as muscle contraction and relaxation [1]. Approximately 80% of phosphorus is present in the bones and teeth of humans and animals [1]. Potassium is essential for cell osmoses, maintaining the general water metabolism as well as maintaining acid/base homeostasis in the body [1, 3].

Research regarding the mineral concentration of meat is often limited to the *Longissimus dorsi* (loin) muscle, as the meat industry accepts this muscle to be the most representative of the total carcass composition of domestic livestock species. This is, however, not always the case with wild and free-ranging species. Blesbok (*Damaliscus pygargus phillipsi*) is a well-known South African antelope species and the second most to be harvested for meat export into the EU and other countries [4]. Blesbok is an example of a free-ranging, ruminant species which grazes. [5]. In this study we therefore investigated the differences in the mineral profiles and concentrations of six commercially important blesbok (*Damaliscus pygargus phillipsi*) muscles.

II. MATERIALS AND METHODS

Slaughtering and sampling

Eight blesbok were harvested (ethical clearance number: 10NP_HOF02, issued by *Stellenbosch University Animal Care and Use Committee*) per season during two seasons (Winter – June of 2010 and Spring – October of 2010) on Brakkekuil farm (34°18'24.0"S and 20°49'3.9"E; 93 m.a.s.l.), Western Cape Province, South Africa. Exsanguination occurred in the field. Partially dressed carcasses were transported to the slaughtering facilities where evisceration and removal of the head, legs and skin occurred (Draft Meat Safety Act, 2000, Act No. 40 of 2000). Two muscles from the forequarters (*Infraspinatus* and *Supraspinatus*), three from the hindquarters (*Biceps femoris*, *Semimembranosus* and *Semitendinosus*) and the *Longissimus dorsi* (loin) muscles were sampled from the left side of each carcass after 24 h of cooling (0° – 5°C).

Mineral analysis

The mineral content of the blesbok muscles was determined on dry, defatted and finely ground samples. Each sample was ashed according to the dry ashing method 6.1.1 (AgriLASA, 2007). An iCAP 6000 Inductive Coupled Plasma (ICP) Spectrophotometer (Thermo Electron Corporation, Strada Rivoltana, 20090 Rodana, Milan, Italy) fitted with a vertical quartz torch and Cetac ASX-520 auto sampler, was used to quantify the mineral elements. Muscle samples were analysed for: phosphorus; potassium; calcium; magnesium; sodium; iron; copper; zinc; manganese; boron; and aluminium content. Consequently the mineral element concentrations were calculated using iTEVA Analyst software. The argon gas flow rate was 2 – 5 $ml.min^{-1}$ and the instrument settings were: camera temperature -27°C; generator temperature 24°C; optics temperature 38°C; RF power 1150 W; pump rate 50 rpm; auxiliary gas flow 0.5 $L.min^{-1}$; nebulizer 0.7 L min^{-1}; coolant gas 12 L min^{-1}; and a normal purge gas flow. Wavelengths for each mineral element were: potassium at 766.490 nm; sodium at 589.592 nm; copper at 324.754 nm; calcium at 317.933 nm; magnesium at 285.213 nm; iron at 259.940 nm; manganese at 257.610 nm; boron at 249.773 nm; zinc at 213.856 nm; phosphorus at 177.495 nm; and aluminium at 167.079 nm. Standards with a high, medium and low range was analysed for quality control, after 11 samples.

Statistical analysis

The mixed model repeated measures of analysis of variances (ANOVA's) was conducted using the Statistica 10 VEPAC module [6]. Fisher LSD was used for post hoc testing. A 5% significance level was used as guideline for determining significant effects. Discriminant Analysis (DA) was conducted [7] so as to indicate the relationship between the mineral profiles of six blesbok muscles. Additional multivariate statistical analysis was performed using XL STAT™ statistical software (Version 2011, Addinsoft, New York, USA).

III. RESULTS AND DISCUSSION

The significant effect of muscle type on the mineral composition of blesbok meat is presented in Table 1. Figure 1 illustrates the differences in the mineral profiles (phosphorus, potassium, calcium, magnesium, sodium, iron, copper, zinc, manganese, boron and aluminium content) of six blesbok muscles. From Fig. 1 it is evident that the largest variation in the mineral profile of blesbok meat is attributed to the difference in the anatomical location of the selected skeletal muscles. The forequarter muscles contained higher concentrations of sodium, calcium and zinc, compared to the three hindquarter (BF, SM and ST) muscles as well as the LD muscles (Table 1). Since the mineral profile (concentrations) of blesbok LD muscles differed significantly from that of the forequarter and to a lesser extent the hindquarter muscles, the nutritional value of blesbok LD muscles cannot be considered a good representation of that of other blesbok skeletal muscles.

The mineral concentration in skeletal muscles is influenced by the concentrations present in the forage consumed by the animal; the latter being influenced by the mineral concentration of the soil [8].

Table 1 Effect of muscle type on the mineral composition (mg.100 g^{-1} dry base) of blesbok meat (Means ± SD)

Minerals	**LD**	**BF**	**SM**	**ST**	**IS**	**SS**
Macro						
Potassium	$169.43^{cd} \pm 17.92$	$183.25^{a} \pm 12.79$	$175.09^{cb} \pm 11.70$	$179.39^{ab} \pm 14.19$	$167.78^{cd} \pm 8.73$	$165.24^{d} \pm 11.66$
Phosphorus	$172.92^{ab} \pm 15.17$	$180.21^{a} \pm 10.36$	$163.67^{c} \pm 6.98$	$172.81^{b} \pm 11.38$	$146.13^{d} \pm 6.77$	$145.48^{d} \pm 8.85$
Magnesium	$30.28^{b} \pm 2.68$	$32.18^{a} \pm 1.72$	$29.89^{b} \pm 1.43$	$30.23^{b} \pm 2.36$	$27.40^{c} \pm 1.67$	$27.17^{c} \pm 2.01$
Sodium	$16.23^{c} \pm 2.68$	$18.82^{b} \pm 1.87$	$18.83^{b} \pm 1.95$	$19.02^{b} \pm 3.50$	$24.73^{a} \pm 3.52$	$23.48^{a} \pm 3.37$
Calcium	$5.51^{b} \pm 1.17$	$5.71^{b} \pm 1.87$	$6.33^{b} \pm 2.16$	$6.05^{b} \pm 1.14$	$7.43^{a} \pm 2.99$	$6.60^{ab} \pm 1.53$
Micro						
Iron	$3.67^{a} \pm 0.51$	$3.58^{ab} \pm 0.25$	$3.55^{ab} \pm 0.76$	$2.85^{c} \pm 0.47$	$3.27^{cb} \pm 0.50$	$3.49^{ab} \pm 0.83$
Zinc	$1.63^{e} \pm 0.28$	$2.52^{c} \pm 0.31$	$3.83^{b} \pm 0.42$	$2.14^{d} \pm 0.33$	$5.61^{a} \pm 0.47$	$5.53^{a} \pm 0.43$
Manganese	$0.04^{a} \pm 0.01$	$0.03^{b} \pm 0.00$	$0.03^{b} \pm 0.01$	$0.03^{bc} \pm 0.01$	$0.02^{d} \pm 0.00$	$0.03^{dc} \pm 0.01$

$^{a\text{-}d}$ Least square means in the same row with different superscripts are significantly different ($p<0.05$)
LD, *Longissimus dorsi*; BF, *Biceps femoris*; SM, *Semimembranosus*; ST, *Semitendinosus*; IS, *Infraspinatus*; SS, *Supraspinatus*

The smallest fraction of the composition of skeletal muscles comprise of minerals. However, meat is generally an essential source of phosphorus, potassium, iron, zinc and magnesium [9] of which potassium, followed by phosphorus are the most important [10]. According to Keeton *et al.* [11], muscle tissue is usually low in calcium (3 – 6 mg.g^{-1}), but rich in potassium (250 – 400 mg.g^{-1}), phosphorus (167 – 216 mg.g^{-1}), sodium (55 – 94 mg.g^{-1}), magnesium (22 – 29 mg.g^{-1}), zinc (1 – 5 mg.g^{-1}), iron (1 – 3 mg.g^{-1}) and copper (0.5 – 0.13 mg.g^{-1}). However, these values refer to *muscle tissue* in general, as apposed to specific *muscles/meat cuts*. The mineral content of meat is influenced by the species, gender, age, hormones, region and diet of the animal [11, 12, 13]. The mineral composition can also differ at anatomical locations within skeletal muscles [14], as a result of different physical activities and consequently fibre type compositions [15]. The latter was found in the six blesbok muscles (Table 1, Fig. 1). Doornenbal *et al.* [15] established that muscle type (*Longissimus dorsi*, *Semimembranosus* and diaphragm) contributed greatest to the variation in mineral content of the meat from grazing cattle, compared to effects of age, sex and breed. The latter was suggested to be due to different physical demands made on each of the skeletal muscles.

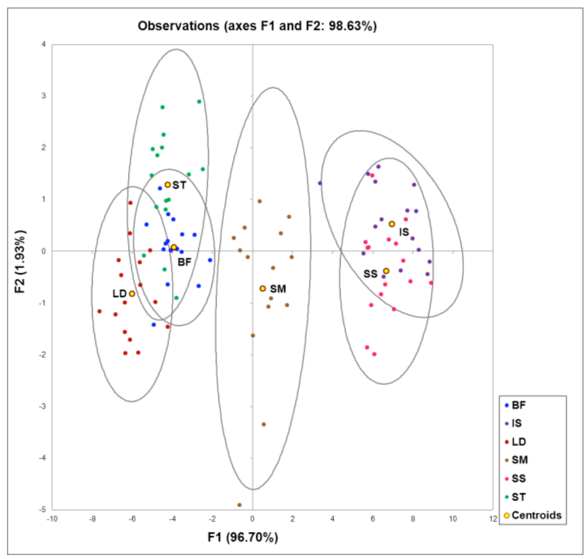

Figure 1. Discriminant Analysis (DA) plot of the mineral composition of six (BF, Biceps femoris; IS, Infraspinatus; LD, Longissimus dorsi; SM, Semimembranosus; SS, Supraspinatus; ST, Semitendinosus) blesbok muscles [16]

It can thus be postulated that a correlation exists between the activity level (muscle fibre type composition) and mineral profiles of the selected blesbok muscles, but to what extent is this true for the skeletal muscles of other free-ranging ruminant species? The significant differences in the mineral profiles (concentrations) of the six blesbok muscles (Table 1, Fig. 1) definitely emphasises the importance of further research aimed at investigating the distribution of essential minerals to skeletal muscles at different anatomical locations in free-ranging ruminants. The differences in the mineral content of skeletal muscles and/or muscle cuts can affect the labelling of subsequent meat products. This definitely warrants further research.

IV. CONCLUSION

The mineral composition (profile) of blesbok carcasses varied significantly between the fore- and hindquarter muscles. This study therefore indicated that blesbok LD muscles can not be assumed to be representative of the total mineral composition of other blesbok muscles or blesbok meat in general. Consequently, mineral concentrations should be indicated for individual skeletal muscles of blesbok, which could be applicable to other free-ranging ruminant species as well. This study thus revealed that the distribution of minerals in the body of free-ranging ruminants is a field of study that warrants further research.

ACKNOWLEDGEMENTS

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the authors and are not necessarily to be attributed to the NRF. The help of the statistician, Prof M. Kidd for statistical analysis of data is appreciated. Special thanks to the Stellenbosch University Food Security Initiative (HOPE Project) for additional financial assistance.

REFERENCES

1. Van der Merwe, F. J. (1983). Dierevoeding. Stellenbosch, South Africa: Kosmo-Uitgewery Edms Bpk.
2. Nelson, C. J. (1999). Nutrient balance across regions of the United States. Journal of Animal Science 76: 287.
3. McDonald, P., Edwards, R. A., Greenhalgh, J. F. D. & Morgan, C. A. (2002). Grass and forage crops. In Animal Nutrition, 6th ed (pp 495-514). Harlow: Pearson Prentice Hall.
4. Anonymous (2011). Game numbers and weights exported for 2010. Oudtshoorn, South Africa: South African Ostrich Business Chamber.
5. Bothma, J. Du P., Van Rooyen, N. & Du Toit, J. G. (2010). Animals and their characteristics. In J. Du P. Bothma & J. G. Du Toit, Game Ranch Management, 5th ed (pp 210-245). Pretoria, South Africa: Van Schaik Publishers.
6. STATISTICA (2011). STATISTICA data analysis software system, version 10.0.228.2. Tulsa, United States of America: StatSoft Inc.
7. Rencher, A. C. (2002). Methods of multivariate analysis, 2nd ed. New York: John Wiley and Sons, Inc.
8. Zomborszky, Z., Szentmihályi, G., Sarudi, I., Horn, P. & Szabó, C. S. (1996). Nutrient composition of muscles in deer and boar. Journal of Food Science 61(3): 625-627.
9. Warriss, P. D. (2000). Meat Science: An Introductory Text (pp 12-36). Wallingford: CABI Publishing.
10. Lawrie, R. A. & Ledward, D. A. (2006). Lawrie's meat science, 7th ed. (pp 128-156). Cambridge, England: Woodhead Publishing Limited.
11. Keeton, J. T. & Eddy, S. (2004). Chemical and physical characteristics of meat/Chemical composition. In W. K. Jensen, C. Devine & M. Dikeman, Encyclopedia of meat sciences (pp 210-218). Oxford: Elsevier Academic Press.
12. Doyle, J. J. (1980). Genetic and non-genetic factors affecting the elemental composition of human and other animal tissues – A review. Journal of Animal Science 50: 1173-1183.
13. Hocquette, J. F., Gondret, F., Baéza, E., Médale, F., Jurie, C. & Pethick, D. W. (2010). Intramuscular fat content in meat-producing animals: Development, genetic and nutritional control, and identification of putative markers. Animal 4(2): 303-319.
14. Zarkadas, C.G., Marshall, W.D., Khalili, A.D., Nguyen, Q., Zarkadas, G.C., Karatzas, C.N. et al. (1987). Mineral composition of selected bovine, porcine and avian muscles, and meat products. *Journal of Food Science, 52(3)*, 520-525.
15. Doornenbal, H., & Murray, A. C. (1981). Effects of age, breed, sex and muscle on certain mineral concentrations in cattle. Journal of Food Science 47: 55-58.
16. Neethling, J. (2012). Impact of season on the composition and quality of male and female blesbok (*Damaliscus pygargus phillipsi*) muscles. MSc (Food Science) thesis. Stellenbosch University, South Africa.