# Effect of feeding Moringa *(Moringa oleifera)* leaf meal on the physico-chemical characteristics and sensory properties of goat meat

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## Abstract

The objective of this study was to determine the physico-chemical characteristics and consumer sensory scores of chevon from crossbred Xhosa lop-eared goats supplemented with *Moringa oleifera* leaf meal (MOL). Twenty-four goats, aged 8 months, were divided into three groups with eight goats in each. All three groups were fed a basal diet of grass hay (GH) *ad libitum* and wheat bran at 200 g/head/day. In addition to the basal diet, the MOL and sunflower seed cake (SC) groups were fed 200 g dried *M. oleifera* leaf meal and 170 g sunflower seed cake, which contained 238 g and 233 g crude protein/kg, respectively, with GH having 141 g. Diet influenced chevon colour. Chevon from MOL- and SC-fed goats had higher values for lightness (L*) 24 h *post mortem*. The redness (a*) values of chevon 24 hours *post mortem* were significantly higher in MOL supplemented goats. Warner Bratzler shear force (WBSF) values of chevon from SC (30.1 N) and MOL (29.8 N) were lower than those for meat from GH diet (32.6 N). Chevon from goats fed GH diet had significantly higher cooking losses (29.5%) than that from the MOL (25.4%) and SC (25.6%) fed groups. Diet influenced the consumer sensory scores of chevon from goats supplemented with MOL, which had higher first bite, aroma, flavour and juiciness scores. Supplementing crossbred Xhosa lop-eared goats with an MOL diet produced chevon with the highest physico-chemical characteristics and consumer sensory scores.

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## Introduction

Goat meat (chevon) is an important protein source for human beings throughout the world, especially in developing countries (Ding *et al.*, 2010; Bakare & Chimonyo, 2011). However, undernourished goats tend to produce poor quality meat (Mushi *et al.*, 2009), which is attributed to poor nutrition and genotype (Madruga *et al.*, 2008). The differences in meat composition may affect the flavour and texture of meat and consequently consumer preferences (Font i Furnols *et al.*, 2009).

The colour of meat depends on several factors and their interactions. It has been established that differences in meat colour are associated with variations in intramuscular fat, level and state of myoglobin and moisture content (Lawrie, 1974; Adam *et al.*, 2010). Bruce *et al.* (2004) reported that meat colour may be influenced by diet, with grass-fed animals having darker meat with lower intramuscular fat than grain-fed ones (Diaz *et al.*, 2002; Priolo *et al.*, 2002; Webb & Erasmus, 2013). Feeding has been reported to affect meat colour, which is attributed to the relationship between lipid and pigment oxidation, particularly the instability of polyunsaturated fatty acids (Lynch *et al.*, 2002, cited by Mancini & Hunt, 2005). Furthermore, meat colour is greatly influenced by the concentration and chemical nature of haemoprotein in the muscle (Madruga *et al.*, 2008). Supplementing goats with forage trees has been observed to improve body weight and general health. Improvement of goats' body weights could have a positive effect on meat quality characteristics (Oni *et al.*, 2010). One such forage tree is *Moringa oleifera* (Sarwatt *et al.*, 2002). *Moringa oleifera* is native to North India and has medicinal, therapeutic and nutritional properties. It has been introduced to warm regions of the world (McKenna *et al.*, 2005). This plant has been recommended as a supplementary feed for dairy cows, goats and fish, since it contains high levels of crude protein in the leaves

(McKenna *et al.*, 2005; Reyes-Sánchez *et al.*, 2006). In addition, it has high levels of antioxidant compounds (Siddhuraju & Becker, 2003), which modulate meat quality (Mielnik *et al.*, 2003).

Chevon has quality attributes that are concordant with present-day consumer demands for leaner and more nutritious meat (Webb *et al.*, 2005; Simela & Merkel, 2008). In South Africa over 50% of goats are reared under the communal farming system, in which there is indiscriminate crossbreeding (Rumosa Gwaze *et al.*, 2009), and the crossbred Xhosa lop-eared goat is one such example. Crossbred Xhosa lop-eared goats are found in considerable numbers in communal areas (Rumosa Gwaze *et al.*, 2009; Bakare & Chimonyo, 2011). They are large framed goats with the potential to increase meat supply owing to higher meat yield and twin kidding ability. The physico-chemical characteristics and consumer sensory attributes of this goat genotype when supplemented with *Moringa oleifera* leaf meal has not been studied. Therefore, the objective of the present study was to determine the physico-chemical characteristics and consumer sensory scores of chevon from crossbred Xhosa lop-eared goats supplemented with *M. oleifera* leaf meal.

**Materials and Methods**

Twenty-four eight-month-old castrated crossbred Xhosa lop-eared goats with a mean initial body weight of 15.2 ± 2.3 kg from the University of Fort Hare's Honeydale farm were used in the study and were managed as described by Moyo *et al.* (2012a). The animals were allocated to three groups of eight goats each, balanced in terms of liveweight and body condition scores. The feeding treatments, namely sunflower seed cake (SC), the positive control; *Moringa oleifera* leaf (MOL); and grass hay (GH), the negative control, were allotted to one of the three groups. The positive control group was fed sunflower seed cake (SC) as a protein source at a level of 170 g/day, while the group fed the MOL diet were given 200 g/day of dried MOL leaves. The GH group did not receive any protein supplement. All goats were supplemented with 200 g wheat bran day as energy source. The feeding period lasted for 60 days. The goats were fed at 08:00 and 15:00 (two equal amounts), and had free access to fresh clean water and grass hay *ad libitum*.

The research protocol was approved and was in compliance with the University of Fort Hare Ethics Committee (clearance number REC-270710-028) on research in animals, and internationally accepted principles for animal use and care (NRC, 1996).

The formulated diets were assessed for dry matter (DM), crude protein (CP), calcium, magnesium, potassium, zinc, copper, iron, manganese and phosphorus, with Association of Official Agricultural Chemists (AOAC, 2005) procedures. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to Van Soest *et al.* (1994). Polyphenols were assayed calorimetrically according to Price & Butler (1977).

The goats were weighed on two consecutive days before slaughter at Adelaide abattoir, South Africa, to obtain final liveweights (FLW). They were fasted for 16 h, and allowed 5 h lairage time, where they were provided only water *ad libitum*. The goats were humanely slaughtered by electrically stunning with 220 - 250 volts, 1.0 - 1.3 A, applied for 1 - 3 seconds, following the Halal slaughter procedure. Warm carcass weights were recorded 1 h after slaughter. The carcasses were chilled overnight at 3 ⁰C with airflow of 1 - 1.5 ms$^2$, then weighed again the following day to obtain the cold carcass weights. At the end of the first 24 hours post slaughter, samples were taken from the *musculus longissimus thoracis et lumborum* for instrumental colour and pH readings.

Muscle pH was measured 1 h ($pH_0$) after slaughter and 24 h ($pH_{24}$) *post mortem* using a digital pH meter (Crison pH 25 instruments S.A., Alella, Spain) equipped with a penetrating electrode. The pH meter was calibrated with pH 4, pH 7 and pH 9 standard solutions (CRISON Instruments, SA, Spain) before each measurement. pH measurements and colour were taken from the *m. longissimus thoracis et lumborum*. Meat colour (L* = lightness, a* = redness and b* = yellowness) was measured with a 45/0 BYK-Gardener instrument (BYK-Gardener GmbH Germany), with a 20 mm diameter measurement area and illuminant D65-day light, 10⁰ standard observer, 24 hours post mortem. Three readings were taken by rotating the instrument 90⁰ between measurements, in order to obtain a representative average value of the colour, and avoiding connective tissue and intramuscular fat. The instrument was calibrated before measurements using the green standard.

Blocks of *m. longissimus thoracis et lumborum* muscle, measuring approximately 7 x 4 x 4 cm, were used to determine cooking loss and shear force values. The muscle was weighed, placed in a water tight PVC plastic bag and cooked in a water bath at 85 ⁰C for 45 minutes, until an internal temperature of 70 ⁰C was attained. The samples were cooled and reweighed. Cooking loss (CL) was calculated using the following formula:

Cooking loss % = [(weight before cooking – weight after cooking) ÷ weight before cooking] × 100

as described by Ding *et al.* (2010). After measurement of cooking loss, cooked samples were used to determine meat Warner Bratzler shear force. Three sub-samples (cut parallel to the muscle fibres with a cross-section of 1 x 1 cm and at least 3 cm long) were removed from each cooked muscle. The sub-samples

were sheared perpendicular to the fibre direction with an Instron Universal Testing Machine (Model 3344, Instron Industrial Products, GC, USA) equipped with a Warner Bratzler (WB) shear force apparatus (cross-head speed at 400 mm/min, one shear in the centre of each core). The measurements were read in Newtons.

Twenty-four hours after slaughter 50 g meat was sampled from LTL and analysed for chemical composition as described by Qwele *et al.* (2013). Total muscle lipids from the MOL, SC and GH groups 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 hydroxytoluence, was added at a concentration of 0.001% to the chloroform/methanol mixture. Fat extracts were dried with a rotary evaporator and the extracts were dried overnight in a vacuum oven at 50 ºC, using phosphorus pentoxide as a mixture adsorbent. Total extractable intramuscular fat was determined gravimetrically from the extracted fat and expressed as percentage (w/w) per 100 g tissue.

*Gluteus medius* meat samples that were used for a consumer sensory evaluation were obtained from each carcass and were cut 24 hours after slaughter. The meat samples were cut into cubes (about 2 x 2 cm), which were placed in watertight PVC plastic bags and cooked in a boiling water bath at a temperature of 85 ºC for 45 minutes (Babikerm *et al.*, 1990). Salt was added to taste. Fifty-four trained consumer panelists of different genders, ages and clans from University of Fort Hare students were used for the consumer sensory assessment of meat. The panelists were taught how to infer and record scores for each variable. The waiting period between meat sample tastings was 10 minutes. Distilled water was served to panelists to freshen their mouths between sub-sample assessments to avoid crossover effects. Eight-point descriptive scales were used to evaluate aroma intensity (1 = extremely bland to 8 = extremely intense), initial impression of juiciness (1 = extremely dry to 8 = extremely juicy), first bite (1 = extremely tough to 8 = extremely tender), sustained impression of juiciness (1 = extremely dry to 8 = extremely juicy), overall tenderness (1 = extremely tough, to 8 = extremely tender), amount of connective tissue (1= extremely abundant to 8 = none), overall flavour intensity (1 = extremely bland to 8 = extremely intense), a-typical flavour intensity (1 = none to 8 = extremely intense). Off-flavour indicators were also assessed.

The PROC GLM procedure of SAS (2003) was used to analyse the effect of diet on slaughter weight, cold dressed weight, dressing percentage, cooking loss, WB shear force, L*, a*, b* and pH values.

The model was:

$$Y_{ijk} = \mu + T_i + E_{ijk}$$

Where:   $Y_{ijk}$   = slaughter weight, cold dress mass, cooking loss, L*, a*, b*, WB shear force values, pH
            $\mu$      = overall mean common to all observations
            $T_i$       = effect of dietary supplementation (grass hay, sunflower cake and *Moringa oleifera* leaf meal)
            $E_{ijk}$   = random error.

The effect of diet on the meat sensory scores was analysed using the general linear model procedure of SAS (2003). The data was tested for normality and was distributed normally. The model was:

$$Y_{ijkl} = \mu + D_i + G_j + T_k + E_{ijkl}$$

Where:   $Y_{ij}$   = response variable (aroma intensity, initial impression of juiciness, first bite, sustained impression of juiciness, fibre and overall tenderness, amount of connective tissue, overall flavour intensity and relevant atypical flavour)
            $\mu$      = overall mean common to all observations
            $D_i$      = effect of dietary supplementation (grass hay, sunflower cake and *Moringa oleifera* leaf meal)
            $G_j$      = effect gender on consumer sensory scores
            $T_k$      = effect of tribe on consumer sensory scores
            $E_{ijkl}$ = effect of tribe on consumer sensory scores.

The PDIFF option in SAS (2003) was used for comparison of means.

## Results

The nutritional composition of the experimental diets given to goats is summarised in Table 1. The MOL and SC diets had significantly higher crude protein levels than the GH diet. *Moringa oleifera* leaf meal and SC diets had higher (*P* <0.05) mineral levels (phosphorus, potassium, zinc, and copper) than the GH diet. There were differences in the concentrations of iron, calcium and sodium in the diets: MOL had the highest (*P* <0.05) concentrations. In addition, the polyphenol values for MOL and SC diets were higher than in GH diet.

The slaughter weights of the goats fed on GH, MOL and SC were 17.5, 20.6 and 20.8 kg, respectively. In addition, the intramuscular fat content of chevon from goats supplemented with MOL (2.39%) and SC

(2.42%) was higher (*P* <0.05) than in the GH group (1.13%). Table 2 shows the effect of diet on muscle pH, colour, shear force values and cooking loss of chevon. There was no difference in the effect of dietary supplementation on pH 24 hours *post mortem*. Diet had an effect on chevon colour with meat from goats supplemented with MOL and SC having higher (P <0.05) values for lightness (L*) at 24 hours *post mortem* than the GH group. Chevon from the MOL diet had higher (a*) values (P <0.05) at 24 hours *post mortem* than those of SC and GH diets. The yellowness (b*) values for meat from goats supplemented with MOL and SC were similar (*P* >0.05) but higher than those supplemented with the GH diet (*P* <0.05) 24 h post slaughter. Shear force values of chevon from SC and MOL were higher (*P* < 0.05) than chevon from the GH diet (Table 2). Chevon from goats supplemented with the GH diet had higher (*P* <0.05) cooking losses than the MOL- and SC-supplemented groups.

The effects of diet on different consumer sensory attributes are shown on Table 3. Diet had an influence (*P* <0.05) on chevon sensory characteristics. Chevon from goats supplemented with the MOL and

**Table 1** Nutritional composition of the experimental diets (DM basis)

| Nutrients | Grass hay | Sunflower meal | *Moringa oleifera* leaf meal | SE |
|---|---|---|---|---|
| Dry matter (g/kg) | 893.3 | 889.3 | 890.0 | 2.2 |
| Crude protein (g/kg) | 140.8[a] | 232.7[b] | 237.6[b] | 3.7 |
| Neutral detergent fibre (g/kg) | 526.7[c] | 420.4[b] | 347.7[a] | 2.9 |
| Acid detergent fibre (g/kg) | 244[b] | 185[a] | 172[a] | 7.5 |
| Phosphorus (g/kg) | 5.0[a] | 6.2[b] | 6.4[b] | 0.1 |
| Calcium (g/kg) | 18.1[a] | 19.8[a] | 27.8[b] | 0.7 |
| Potassium (g/kg) | 17.4[a] | 19.2[b] | 2.03[b] | 0.4 |
| Sodium (mg/kg) | 0.1[a] | 0.1[a] | 0.2[b] | 0.01 |
| Zinc (mg/kg) | 770[a] | 889[b] | 892[b] | 33.8 |
| Copper (mg/kg) | 127[a] | 197[b] | 210[b] | 6.3 |
| Iron (mg/kg) | 2860[a] | 3257[b] | 3560[b] | 22.0 |
| Polyphenols (g/kg) | 4.3[a] | 6.7[b] | 7.7[b] | 0.2 |

[abc] means with different superscripts in a row are significantly different (*P* <0.05).
SE: standard error.

**Table 2** Effect of diet (grass hay, *Moringa oleifera* leaf meal and sunflower seed cake) on muscle pH, colour, shear force values and cooking loss

| Variables | Diets | | |
|---|---|---|---|
| | Grass hay | *Moringa oleifera* | Sunflower cake |
| Muscle pH | | | |
| $pH_0$ | 6.6[b] ± 0.08 | 6.3[a] ± 0.08 | 6.4[b] ± 0.08 |
| $pH_{24}$ | 5.7 ± 0.05 | 5.6 ± 0.05 | 5.6 ± 0.05 |
| $pH_{0-24h}$ | 0.9[b] ± 0.16 | 0.7[a] ± 0.16 | 0.8[a] ± 0.18 |
| Colour after 24 h | | | |
| L* | 40.7[a] ± 0.4 | 44.9[b] ± 0.4 | 43.6[b] ± 0.4 |
| a* | 10.5[a] ± 0.2 | 13.1[c] ± 0.2 | 12.5[b] ± 0.2 |
| b* | 7.1[a] ± 0.04 | 8.4[b] ± 0.04 | 7.9[b] ± 0.04 |
| Shear force (N) | 32.6[b] ± 0.10 | 29.8[a] ± 0.10 | 30.1[a] ± 0.10 |
| Cooking loss (%) | 29.5[b] ± 0.48 | 25.4[a] ± 0.48 | 25.6[a] ± 0.48 |

[abc] means with different superscripts in a row are different (*P* <0.05).
L*: lightness; a*: redness; b*: yellowness; N: Newtons.

SC diets had higher (*P* <0.05) aroma intensity scores than of goats supplemented with GH diet. Other sensory characteristics scores differed (*P* <0.05) with the diet offered to goats. Female respondents gave higher (*P* <0.05) scores than male respondents on chevon aroma intensity. Xhosa consumers gave lower (*P* <0.05) aroma intensity scores than the Ndebele, Shona and Zulu consumers.

**Table 3** Effect of diet (*Moringa oleifera* leaf meal, sunflower seed cake and grass hay) on sensory characteristics

| Treatments | Sensory characteristics | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Aroma intensity** | **Initial juiciness** | **First bite** | **Sustained impression of juiciness** | **Overall tenderness** | **Connective tissue** | **Overall flavour** | **Atypical flavour** |
| Control (GH) | 4.2[a] ± 0.12 | 4.5[a] ± 0.11 | 5.1[a] ± 0.11 | 4.4[a] ± 0.17 | 4.6[a] ± 0.11 | 4.1[a] ± 0.01 | 4.2[a] ± 0.01 | 2.6[b] ± 0.18 |
| Sunflower | 4.5[b] ± 0.12 | 4.9[b] ± 0.11 | 5.0[a] ± 0.11 | 4.9[b] ± 0.11 | 6.1[c] ± 0.11 | 4.8[b] ± 0.09 | 4.8[b] ± 0.10 | 1.9[a] ± 0.18 |
| *M. oleifera* | 4.7[b] ± 0.12 | 5.1[c] ± 0.11 | 5.4[b] ± 0.11 | 5.5[c] ± 0.11 | 5.7[b] ± 0.11 | 4.7[b] ± 0.09 | 4.7[b] ± 0.01 | 1.8[a] ± 0.18 |

[abc] values within the same column with different superscripts are significantly different (*P* <0.05).
GH: grass hay; *M. oleifera*: *Moringa oleifera*.

## Discussion

The higher redness (a*) values for goats supplemented with the MOL diet could be attributed to high levels of dietary iron in the MOL used in this study. According to Kadim *et al.* (2003), the paleness of chevon could be due to its low concentration of muscle pigment. The values for lightness (L*) and redness (a*) reported in this study were lower than those of Ding *et al.* (2010) for chevon from Guanzhoung dairy goats. In the current study, the effect of supplementation on lightness (L*) value of *m. longissimus dorsi* muscles at 24 h *post mortem* was apparent, with goats in the MOL group having paler chevon than the other two groups.

Chevon from goats supplemented with MOL showed greater (*P* <0.05) a* and b* values than the other treatments. This could be attributed to the influence of polyphenolic compounds in the MOL, which have antioxidant properties (Moyo *et al.*, 2012b). Dietary antioxidant indirectly modifies chevon colour, probably by decreasing haemoglobin oxidation and activating mechanisms that modify pigment distribution in animal tissues (Simitzis *et al.*, 2008). Dietary antioxidants also minimize rancidity, and retard lipid peroxidation without damage to sensory or nutritional properties of meat, resulting in quality maintenance and enhanced shelf life (Jang *et al.*, 2008; Lahucky *et al.*, 2010; Qwele *et al.*, 2013).

Chevon from MOL- and SC-supplemented goats had more (*P* <0.05) subcutaneous and intramuscular fat compared with the GH group (Qwele *et al.*, 2013). The WB shear force values (29.8 to 32.6 N) reported in this study are lower than those (between 29.8 to 35.6 N) of Marume (2010) and were slightly more tender than a value of 55 N, which is a benchmark for exceptionally tough meat. Exceeding 55 N would be considered objectionably tough by trained sensory panels and consumers (Abdullah & Musallam, 2007; Mushi *et al.*, 2009). The tenderness in SC and MOL meat could be due to a higher amount of intramuscular fat, but within the normal ranges reported elsewhere (Dhanda *et al.*, 2003; Kadim *et al.*, 2003).

Chevon from the MOL group had higher (*P* <0.05) aroma intensity (AI) scores (4.7) than the SC (4.5) and GH groups (4.2). Chevon from goats supplemented with MOL and SC had higher slaughter weight and intramuscular fat content, which contributed to high aroma intensity scores. Chevon from goats supplemented with MOL and SC had higher (*P* <0.05) flavour scores, which could be attributed to higher fat content and high antioxidant content in MOL meat (Qwele *et al.*, 2013). Borton *et al.* (2005) and Priolo *et al.* (2002) found that flavour was more intense in chevon from animals that were fed concentrates than from animals that grazed pastures.

Female consumers in the current study were observed to give higher scores in most sensory attributes, hence finding chevon more acceptable. Similar observations were made by Simela *et al.* (2008) and Xazela (2011). In addition, Mahanjana & Cronje (2000) and Dyubele *et al.* (2010) reported that factors such as gender, clan and age tended to affect the acceptability of chevon from one community to the next. In the current study, tribe had an influence on chevon acceptability, as reflected by Xhosa generally giving low scores in all sensory attributes compared with the other two clans.

## Conclusion

It was concluded that supplementing crossbred Xhosa lop-eared goats with *M. oleifera* leaf meal produced chevon of comparable quality with sunflower seed cake with higher meat quality attributes, reflected in higher sensory consumer scores compared with the control group.

## Acknowledgements

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