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Short communication

Dietary supplementation of *Moringa oleifera* silage increases meat tenderness of Assaf lambs

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ABSTRACT

It is well-recognized, that dietary manipulation can alter the quality of lamb meat. *Moringa-oleifera* was previously shown to improve livestock product quality. In the current research, we tested the effect of dietary ensiled *Moringa oleifera*, accounting for 6.8% of TMR, on quality characteristics of *longissimus lumborum* (LL) muscle of growing Assaf lambs. Steaks of Moringa-fed lambs were tenderer (27.5 ± 4.72 N), comparing to the controls (34.8 ± 4.28N), by means of shear-force (SF; $P \leq 0.01$), and characterized by longer sarcomeres (2.24 ± 0.23 and 1.88 ± 0.11 μm, respectively; $P \leq 0.001$) and lower intra-muscular fat (IMF) content (3.83 ± 1.60 and 5.94 ± 1.82%, respectively; $P \leq 0.05$). No difference was revealed between groups in collagen content (CC). It is suggested that *Moringa oleifera* based dietary manipulation could be implemented in order to design a tender and lean lamb meat.

1. Introduction

Consumer's choice of fresh meat is affected by appearance, eating and reliance quality traits (Acebron and Dopico, 2000; Becker, 2000; Troy and Kerry, 2010). Of these, edible traits and particularly tenderness is the most accepted quality parameter, (Lomiwes et al., 2014; Maltin et al., 2003). Meat tenderness varies in a great extent within and between animals and muscles types. Breed, genotype, sex, age, nutrition and pre/post slaughtering procedures are key factors underlying this variability (Guzek et al., 2015).

Meat tenderness depends on the intrinsic physiological characteristics of the live muscle, as well as different processing elements developed following rigor (Starkey et al., 2016; Young et al., 2005). Sarcomere length (SL) is one of the major factors that meat tenderness has been attributed to (Rhee et al., 2004). Sarcomere length dictates the overall length of fibers, and has a crucial role in the mechanical structure of the muscle (Guzek et al., 2015; Wick and Marriott, 1999). The interaction between SL and meat tenderness has extensively been explored, with most studies indicating positive correlations between SL and meat tenderness (Celia et al., 1992; Hopkins and Thompson, 2001; Rhee et al., 2004; Smulders et al., 1990).

Possible influence on meat tenderness is also expected from muscle fiber type, through interactions with SL. Indeed, SL may be associated with the dominant type of fibers in the specific muscle (Guzek et al., 2015).

In lamb as in beef, there is great variation in the perception of meat quality among consumers, emphasizing the need to improve its sensory characteristics, while also here, tenderness is considered a key trait to grade palatability (Jacob and Pethick, 2014; Safari et al., 2002). Sheep accounts for only about 3% of the meat market worldwide, rendering lamb meat still a niche product (Jacob and Pethick, 2014). Thus, in spite of the unique aroma and flavor attributed to lamb meat (Jacobson and Koehler, 1963; Jamora and Rhee, 1998), and potentially high nutritional values (Wood et al., 2008; Raes et al., 2004), the awareness of consumers to lamb meat quality did not increase over the years (FAO, 2014). Controlling tenderness seems, therefore, an appropriate attitude by which consumers purchasing habits for lamb meat would be positively affected (Safari et al., 2002).

It is well-recognized that different dietary conditions can alter the quality of meat in different sheep breeds (Badee and Hidaka, 2014;

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Francisco et al., 2015; Holman and Malau-Aduli, 2013; Kotsampasi et al., 2014; Turner et al., 2014).

Among the available forage crops, special focus has been given to the effects of *Moringa oleifera* on livestock growth and production (Qwele et al., 2013; Sultana et al., 2015). *Moringa oleifera* is a rich source for crude protein (CP; varies between 20 and 29% in the leaves) and vitamins (Ferreira et al., 2008; Foidl et al., 2001; Makkar and Becker, 1996), and possesses significant anti-oxidative potential (Verma et al., 2009), attributed to polyphenols, tocopherols and carotenoids in the foliage. These nutritional traits along with high production of leaf mass, adaptability to grow in all types of soils and tolerance of extreme temperatures, have turned Moringa a potential high quality feed source for livestock (Foidl et al., 2001; Sanchez and Ledin, 2006).

However, while most studies focused on supplementation of dried Moringa leaves to ruminant's diet, only very few used Moringa in the form of silage as a dietary supplement (Cohen-Zinder et al., 2016; Mendieta-Araica et al., 2011). Although applied on dairy cattle, the recent study of Cohen-Zinder et al. (2016) provides a hint as for the potential of *Moringa oleifera* silage to affect ruminants' product quality (Cohen-Zinder et al., 2016). Therefore, in the current research, we aimed to explore whether dietary supplementation of Moringa silage to Assaf lambs, would improve their meat quality variables, with emphasis on meat tenderness.

2. Methods

2.1. Animal population and diets preparation

Sixteen randomly selected Assaf lambs participated in the current study, carried out in a commercial sheep herd in Moshav Udim (Israel). All procedures involving animals were approved by the Israeli committee for animal care and experimentation. At an average age of 54 days, the lambs were divided into control (n = 8) and Moringa-fed (n = 8) groups. The groups of lambs were located in two equal sized, neighboring paddocks (without replications) with free access to water and food. Initial average body weights (BW) were 25.9 kg (SE ± 0.86) and 25.8 kg (SE ± 0.88), for the control and Moringa-fed lambs, respectively. Each group of lambs was fed with a different total mixed ration (TMR), either Moringa oleifera-silage or control diet. Diets were freshly prepared and served to the lambs once daily, at 0600.Composition of the Moringa and control TMRs is presented in Table 1. Briefly, the Moringa TMR was composed of *Moringa oleifera* silage that was prepared as in Cohen-Zinder et al. (2016), accounting for 6.8% of DM. Total mixed rations were served to the lambs once daily. Total mixed rations were designed for ad-libitum consumption plus 10% orts. Average daily dry matter intake (DMI; g/day/lamb) was determined in each group based on the DM content in the TMRs and feed refusals. Body weight was recorded by automatic scale (SHEKEL Ltd, Israel) every 10 days. Body weight gain (BWG) was calculated as the difference between the final and initial BW, divided by the entire experimental period, *i.e.*, 90 d. Lambs were slaughtered at the age of 144 d.

Table 1
Ingredients of the diets, fed to growing Assaf lambs.

Composition (g/kg DM)	Moringa	Control
Moringa silage[a]	182.0	–
Wheat hay	–	53
Corn grain, whole	205	237
Barley grain, whole	185	214
Wheat grain, whole	98.2	114
Sugar-cane molasses	8.2	9.5
Concentrated pellets [b,c]	321.6	372.5

[a] Moringa silage = *Moringa oleifera* silage composed of a mixture on DM basis of: fresh *Moringa oleifera* foliage + soybean hulls + sugar-cane molasses (at proportion of 37.2: 57.8: 5.0, respectively), ensiled in pressed bales wrapped with polyethylene stretched films.

[b] Concentrated pellets contained a mix of (g/kg mix DM): wheat bran, 220; soybean meal, 201; gluten feed, 100; sunflower meal, 240; canola meal, 50; ground wheat grain, 128; $CaCO_3$, 25; NaCl. 10; soy oil, 8; Ammonium chloride, 10; Sodium sulphate, 6; Vitamins + minerals mix[3], 2.

[c] Vitamins + minerals mix contained (g/kg mix DM): Zn, 24; Fe, 24; Mn, 24; I, 1.44; Co, 0.32; Se, 0.32; 16,000,000 IU of vitamin A; and 40,000 IU of vitamin E).

Table 2
Chemical composition of the *Moringa oleifera* and Control diets fed to growing lambs.

Composition (g/kg DM)	Moringa	Control
Dry matter (g/kg wet TMR)	732 ± 0.57[a]	822 ± 0.08[b]
Organic matter	922 ± 0.07[a]	924 ± 0.24[b]
Crude protein	208 ± 0.30[a]	197 ± 0.11[b]
Ether extract	20.9 ± 0.05[a]	17.8 ± 0.02[b]
Neutral detergent fiber (NDF)	274 ± 0.66[a]	263 ± 0.39[b]
Non-structural carbohydrate	446 ± 0.52[a]	419 ± 0.84[b]
In vitro DM digestibility	0.803	0.808

[a,b] – Indicate significant differences ($P < 0.05$) between control and *Moringa oleifera* diets.

The chemical composition of the two TMRs is presented in Table 2. Dry matter content of TMRs was determined after drying the samples in an air-forced oven for 48 h at 60 °C. The dry samples were ground through a Wiley mill (Philadelphia, PA, USA), using a 1 mm screen before chemical analyses were performed. Ash, CP and ether extract (EE) were determined according to AOAC (1990). Neutral detergent fiber (NDF) was analyzed with heat-stable amylase and without Na-sulfite according to the method of Van Soest et al. (1991), by an ANKOM fiber analyzer (ANKOM220 Technology, Macedon, NY, USA), and expressed inclusive of residual ash. Non-structural carbohydrate (NSC) was determined as: NSC = OM − NDF − CP − EE.

In-vitro DM digestibility of TMRs was calculated in the dried ground samples according to the two-stage technique of Tilley and Terry (1963).

2.2. Slaughtering and sampling

Lambs of the two groups were transported (1.5 h) to a licensed slaughterhouse (Haifa abattoir, Israel), held in a barn overnight and slaughtered as a single group on the following morning. Due to some technical issues in the slaughterhouse, two lambs were excluded from the experiment. As a result, carcass parameters and meat samples were collected from six animals only in the Moringa-fed group (n = 6). The control group had no changes in lamb number (n = 8). After slaughter, carcasses were trimmed and gradually chilled, initially at 18 °C for several hours (± 7 h) to avoid cold shortening, then hanged overnight at 1 °C in the chilling room.

The *longissimus lumborum* (LL) muscle of right and left side was boned out from the 12/13th rib to the lumbar sacral junction. The subcutaneous fat and epimysium were then removed from each muscle, which was divided into sections and used (right side) for SL (20 g), collagen content, fatty acid profile and chemical analyzes. The left side *longissimus* muscle was used for shear-force (SF) analysis (± 200 g). For ageing, steaks were sealed in plastic bags. Following two days of ageing at 0–2 °C, steaks were frozen at 20 °C for further analyzes.

2.3. Meat quality parameters: instrumental and chemical measurements

2.3.1. pH and color

A pH-meter equipped with a spear-head electrode (Meat pH-meter; Hannah instruments, Model #HI99163; Serial #B0083102) was used to measure the initial pH (pHi) 45 min post-slaughtering in the 12th rib region of the *longissimus* muscle of the warm carcass. The ultimate pH (pHu) was measured 24 h later in the mid region of the meat samples (=steaks). The pH-meter was calibrated before each set of recordings