Small Ruminant Research xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Research Paper

Extract of *Moringa oleifera* leaves improves feed utilization of lactating Nubian goats

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ARTICLE INFO

Keywords:
Feed utilization
Moringa oleifera
Nubian does
Phytogenic extracts
Ruminal fermentation

ABSTRACT

The present experiment aimed to assess the effect of providing oral doses of *Moringa oleifera* leaf extract on feed intake, nutrient digestion, and ruminal and blood serum measurements in goats. Sixteen lactating Nubian does (36.5 ± 0.6 kg) were used in a quadruplicated 4 × 4 Latin square design over an 88-day period. An aqueous *M. oleifera* extract was supplemented orally to each doe at doses of 0 (Control treatment), 10 (ME10 treatment), 20 (ME20 treatment) or 40 mL (ME40 treatment). Compared with control, *M. oleifera* extract linearly increased ($P < 0.01$) nutrient intake and digestibility of dry matter, organic matter, and neutral detergent fiber, without affecting digestibility of crude protein and ether extract. Without affecting ruminal pH and ammonia-N, *M. oleifera* extract increased ($P < 0.05$) total short-chain fatty acids (SCFA), branched-chain SCFA, and propionic acid concentrations; however, the extract linearly decreased ($P < 0.01$) acetic/propionic ratio and calculated methane production. Increased ($P < 0.01$) serum albumin and glucose concentrations, and decreased ($P < 0.05$) cholesterol, triglycerides, glutamic oxaloacetic transaminase and glutamic pyruvic transaminase concentrations were noted with the inclusion of *M. oleifera* extract. It is concluded that an oral dose of *M. oleifera* extract enhanced feed intake and digestibility and ruminal fermentation in lactating Nubian does. Although further research is needed, performance responses associated with increasing the dose of *M. oleifera* extract to 40 mL/doe were not large; thus, the 20 mL dose is recommended for practical use.

1. Introduction

Increasing feed utilization and productive performance of ruminants through improving animal health and feed utilization and by altering the microbial ecosystem and ruminal function are the main goals of animal nutritionists and microbiologists. The inclusion of antibiotics and ionophores enhances feed efficiency and nutritive value; however, increased regulations and public concerns about their metabolites and residues, as well as anti-microbial resistance, have compelled researchers to explore alternative strategies to improve performance (Matloup et al., 2017). Potential alternative strategies to replace antibiotics include the use of exogenous enzymes (Morsy et al., 2016), live yeast (Hassan et al., 2016), herbal plants (Kholif et al., 2017a), phytogenic extracts (Valdes et al., 2015), and essential oils (Matloup et al., 2017) to enhance nutrient utilization and animal productivity.

Moringa oleifera Lam (syns. *Moringa pterygosperm*, family *Moringaceae*) is a tree distributed almost worldwide. *M. oleifera* is a good source of protein (Kholif et al., 2015, 2016) with an excellent fatty acid and amino acid profiles (Sánchez-Machado et al., 2010). Moreover, *M. oleifera* is rich in bioactive compounds such as essential oils, saponins, and tannins, which are present in different parts of the plant (Mendieta-Araica et al., 2011a; Salem et al., 2014; Kholif et al., 2015, 2016). These compounds often have some antimicrobial and anthelmintic properties, which can improve feed utilization by ruminants and animal performance (Valdes et al., 2015). Phytogenic extracts and plant parts containing these bioactive compounds might provide a low-cost alternative for improving feed utilization and lactational performance (Mendieta-Araica et al., 2011a; Kholif et al., 2015), and experimental evidence suggests that phytogenic extracts in diets of ruminants can improve feed efficiency and animal productivity (Valdes et al., 2015). The positive effects of such phytogenic extracts are mainly a result of the secondary metabolites such as tannins and saponins, which have the

Abbreviations: ADF, acid detergent fiber expressed exclusive of residual ash; BW, body weight; CH_4, methane; CF, crude fiber; CP, crude protein; DE, digestible energy; DM, dry matter; EE, ether extract; GOT, glutamate-oxaloacetate transaminase; GPT, glutamate-pyruvate transaminase; ME, metabolizable energy; NDF, neutral detergent fiber expressed exclusive of residual ash; NFE, digestible nitrogen free extract; NSC, non-structural carbohydrates; OM, organic matter; SCFA, short-chain fatty acids; TDN, total digestible nutrients

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http://dx.doi.org/10.1016/j.smallrumres.2017.10.014
Received 13 April 2017; Received in revised form 4 August 2017; Accepted 31 October 2017

Table 1
Composition of ingredients and experimental basal diet fed to the lactating Nubian goats (g/kg DM basis).

Item	Crushed yellow corn	Soybean meal	Wheat bran	Berseem clover (*Trifolium alexandrinum*)	Basal (Control) diet[1]
Dry matter (g/kg wet material)	866	889	871	141	564
Organic matter	890	928	852	882	874
Crude protein	91	408	130	133	173
Ether extract	45	21	56	25	32
Non-structural carbohydrates	540	356	204	301	370
Neutral detergent fiber	214	143	462	423	299
Acid detergent fiber	89	96	131	324	186
Lignin	10	9	38	48	27
Cellulose	79	87	93	276	159
Hemicellulose	125	47	331	99	113

[1] The control diet consisted of (per kg DM): 400 g of Egyptian berseem clover (*Trifolium alexandrinum*), 300 g crushed corn, 200 g soybean meal, 80 g wheat bran, 10 g limestone, 5 g salt, and 5 g mineral and vitamin mixture [containing per kg: 141 g Ca, 87 g P, 45 g Mg, 14 g S, 120 g Na, 6 g K, 944 mg Fe, 1613 mg Zn, 484 mg Cu, 1748 mg Mn, 58 mg I, 51 mg Co, 13 mg Se, 248000 IU vitamin A, 74000 IU vitamin D_3, and 1656 IU vitamin E].

ability to alter ruminal fermentation (Salem et al., 2014). To the best of our knowledge, no information is available on the effect of an aqueous *M. oleifera* extract on feed efficiency; however, several studies on the inclusion of *M. oleifera* leaves or silages in diets of lactating cows, sheep and goats have been published (Sultana et al., 2015; Babiker et al., 2016; Zeng et al., 2017). More recently, inclusion of *M. oleifera* leaves in ruminant diets resulted in quantitative and qualitative improvement in animal performance (Mendieta-Araica et al., 2011b; Cohen-Zinder et al., 2016; Kholif et al., 2016).

We hypothesized that the bioactive compounds in an aqueous *M. oleifera* extract will enhance feed utilization and ruminal fermentation of does. Therefore, the present study aimed to investigate the effect of providing the extract orally at different doses on nutrient utilization, digestibility, and ruminal fermentation in lactating does.

2. Materials and methods

2.1. Moringa oleifera extract preparation

Plant leaves of *M. oleifera* were collected randomly from several young and mature trees, freshly chopped into 1- to 2-cm lengths, and immediately extracted at 1 kg dry matter (DM) leaf/8 L of water. Plant materials were soaked and incubated in water at 25–30 °C for 72 h in closed 25-L jars. After incubation, jars were heated to 39 °C for 1 h, and then immediately filtered with gauze, discarding the solid fraction and retaining the liquid fraction for further use. The extract was prepared weekly and stored at 4 °C for daily use.

The concentration of total tannins in *M. oleifera* leaves was determined according to Makkar (2003), and total phenolic content was determined chromatographically as described by Meier et al. (1988). Assuming 100% extraction efficiency, 8 L of the extract would contain 22 g total tannins and 48 g total phenolics or 2.75 g of tannins and 6 g of total phenolics per liter. As previously reported in Kholif et al. (2017b), for determination of chemical constituents of the extract, *M. oleifera* leaves (100 g) were soaked in 150 mL of methanol, acetone, and hexane (1:1:1 v/v; HPLC grade) solvent at room temperature. After 24 h of soaking, the extract was filtered through Whatman No.1 paper and over active charcoal to remove chlorophyll. The extract was then concentrated to 20 mL and lyophilized with a freeze dryer (Alpha 1–4 LDplus, Martin Christ, Osterode am Harz, Germany) to obtain dried extract (Valdes et al., 2015). At the Central Laboratory of National Research Centre (Egypt), 10 mL of the extract was analyzed using GC–MS (Thermo Scientific, Trace GC Ultra/ISQ Single Quadrupole MS, TG-5MS fused silica capillary column (30 m long, 0.25 mm internal diameter, and 0.1-mm film thickness)). For GC–MS detection, an electron ionization system with ionization energy of 70 electron volts (eV) was used, and helium was the carrier gas at a constant flow rate of 1 mL/min. Injector and MS transfer line temperatures were set at 280 °C. Quantification of all the identified components was investigated using the percent relative peak area. A tentative identification of the compounds was performed based on the comparison of their relative retention time and mass spectra with those of the NIST, WILLY library data of the GC–MS system. A total of 30 peaks from the leaf extract of *M. oleifera* were detected in the GC–MS chromatograms, with the retention time ranging from 16.64 to 61.11 min; all were identified as C_{10} to C_{43} compounds.

2.2. Does, feeding and experimental design

Does were cared and handled in accordance with the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 2010). During the first week of lactation, sixteen lactating Nubian does, weighing 36.5 ± 0.6 kg body weight (BW), were randomly assigned to four experimental treatments in a quadruplicated 4 × 4 Latin square design, with four treatments, four periods and four does per treatment within each period, resulting in 16 replicates per treatment for the experiment. The experimental treatments were assigned randomly to the four groups in the first period, after which a predetermined sequence was followed that allowed each doe to receive each treatment.

Does were individually housed in soil-surfaced pens (1.5 m^2/doe) under shade without bedding and with free access to water. They were offered the experimental diets to meet their nutrient requirements according to NRC (2007) recommendations. Adjustments were made to the feed offered to ensure collection of orts. Does were weighed at the beginning and at the end of each experimental period. The basal diet fed to the does contained (per kg, DM basis): 400 g of Egyptian berseem clover (*Trifolium alexandrinum*), 300 g crushed yellow corn, 200 g soybean meal, 80 g wheat bran, 10 g limestone, 5 g minerals/vitamins mixture, and 5 g table salt. The chemical composition of the ingredients and basal diet is shown in Table 1.

Does were fed the basal diet supplemented with the extract at (per doe daily): 0 mL (Control treatment), 10 mL (ME10 treatment), 20 mL (ME20 treatment), or 40 mL (ME40 treatment). Diets were offered to each doe individually at 08:00 and 16:00 h in two equal portions. The extract was administered orally to individual does, once daily, with a 20-mL syringe before the morning feeding at 08:00 h to ensure the full dose was received. Each experimental period lasted 22 days; 15 days of adaptation to the new diet and 7 days for sample collection (sampling of feed and orts, feces, ruminal fluid, and blood). Milk yield, composition and fatty acids profile also were measured during the last 7 days of each period, but those data are not reported in the present manuscript.

2.3. Nutrient digestibility, and chemical analyses

During the collection period (i.e., the last 7 days of each period), feed intake was recorded daily by weighing the offered diets and