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Moringa oleifera leaf meal as a protein source in lactating goat's diets: Feed intake, digestibility, ruminal fermentation, milk yield and composition, and its fatty acids profile

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ABSTRACT

Sixteen lactating Anglo-Nubian goats (36.2 ± 0.7 kg BW) were used in quadruplicated 4 × 4 Latin square design to evaluate the inclusion of *Moringa oleifera* leaf meal (MLM) in their diets. *M. oleifera* leaf meal inclusion rates were 0 (M0 or control, no MLM, only sesame meal), 10 (M10), 15 (M15) and 20% (M20), replacing sesame meal by 0 (control), 50, 75 and 100%, respectively. Goats fed on M15 and M20 diets showed increased feed intake of most nutrients ($P < 0.05$). Moreover, dry matter, organic matter, and fibre digestibilities were increased ($P < 0.05$) with M15 diet. Goats fed on M15 diet showed increased ($P < 0.05$) ruminal pH, volatile fatty acids and propionate concentrations compared to the control diet. Blood glutamic-pyruvic transaminase concentration was increased ($P < 0.05$), and urea-N and cholesterol concentrations were decreased ($P < 0.05$) in goats fed MLM diets. Milk yield and energy corrected milk were increased ($P < 0.01$) in goats fed MLM, and the greatest increase was observed in the group fed the M15 diet. Feeding MLM also affected milk composition increasing ($P < 0.05$) total solids and lactose contents. Milk components outputs were increased in goats fed MLM compared to control ($P < 0.01$). The relative percentage of saturated fatty acids was decreased ($P < 0.05$), and those of unsaturated (mono- or poly-) fatty acids and of conjugated linoleic acid were increased ($P < 0.05$) in the milk of goats fed M15 and M20 diets. *M. oleifera* can replace sesame meal as a protein source in diets for lactating goats. The inclusion of MLM increased feed intake, enhanced nutrient digestibility and ruminal fermentation, increased milk yield and modified milk fatty acid profile positively. An inclusion rate of 15% MLM (replacing 75% of sesame meal) in the diet was the most suitable level for lactating goats under the current experiment conditions.

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1. Introduction

The availability and price of concentrates, in particular of protein sources, are a serious problem for animal producers, especially for small farms stakeholders. Consequently, there is a need for alternative ingredients with high protein content and balanced amino acids profile, and with a suitable cost. Plants leaf meal, forage trees, saltbush and shrubs are good and cheap sources of protein (Mendieta-Araica et al., 2011a; Alsersy et al., 2015; Salem et al., 2006, 2015).

One of these potential tree forages is *Moringa oleifera* Lam (syns. *Moringa pterygosperm*, family *Moringaceae*), which grows throughout the tropics (Debela and Tolera, 2013). *M. oleifera* is an indigenous native tree from the Himalaya (Duke, 2001) but, at present, it is widely distributed almost worldwide (Soliva et al., 2005). *M. oleifera* can be grown in humid, hot, dry tropical and subtropical regions. It is a drought tolerant plant that can grow in all types of soils, except those that are waterlogged (Abdul, 2007), and can tolerate dry seasons lasting up to 6 months (Mendieta-Araica et al., 2013). The yield per ha varies widely depending on season, variety, fertilization, irrigation regimen, accession and ecological zone (Palada et al., 2007). Reported yields range from 43 to 115 tonnes of biomass ha^{-1} $year^{-1}$ (Foidl et al., 2001; Safwat et al., 2014), with about 4.2–24 tonnes ha^{-1} $year^{-1}$ of dry matter (DM) (Reyes-Sánchez et al., 2006; Nouman et al., 2014). Most of the production is located in India with 1.1–1.3 million tonnes $year^{-1}$ harvested from 38,000 ha (Patel et al., 2010). No information is available about the global and Egyptian production of *M. oleifera* leaves or seeds. In Egypt, *M. oleifera* is grown for human consumption; however, the low price of foliage encourages its use as animal feed. The price per kg DM varies considerably from 1 to 1.5 US$ for dried leaves up to 20–24 US$ for seeds. The price of branches with leaves and soft twigs as animal feed can be around 0.25–0.5 US$ per kg DM. *M. oleifera* leaf meal (MLM) contains from 179 to 268 g crude protein (CP)/kg DM (Sultana et al., 2015), with about 47% of bypass protein (Becker, 1995) and with adequate amino acid profile (Sánchez-Machado et al., 2010). The chemical composition of MLM can vary considerably depending on the proportions of small branches, twigs and leaf (Mendieta-Araica et al., 2011a), stage of maturity, time of sampling and *Moringa* species (Debela and Tolera, 2013), and agro-ecological zone where trees are growing (Sultana et al., 2015).

Experiments including *Moringa* fresh foliage in the diets of goats (Sultana et al., 2015), sheep (Fadiyimu et al., 2010) and cows (Mendieta-Araica et al., 2011b) have reported improved feed utilization and animal productive performance. Mendieta-Araica et al. (2011b) fed dairy cows fresh or ensiled *Moringa* foliage *versus* Elephant grass and reported unaffected live weights and milk yield and composition with increasing intake of fresh *Moringa*, in spite of higher CP and fibre digestibilities for ensiled *M. oleifera*. Moreover, Fadiyimu et al. (2010) included *M. oleifera* at different levels in diets for sheep, and reported decreased intake with increasing *M. oleifera* in the diet, but with increased nutrients digestibility.

Little information about *M. oleifera* as a protein source in the diet of ruminants is available. Therefore, the aim of this study was to evaluate the effects of replacing partially or completely a conventional protein source (sesame meal) with MLM in diets for lactating Anglo-Nubian goats on feed intake, digestibility, blood chemistry, and milk yield and composition.

2. Materials and methods

Goats were cared and handled in accordance with the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999). The trial was conducted at a family owned commercial dairy farm near Behera governorate (Egypt) and at the Laboratory of Dairy Animal Production, National Research Centre (Egypt). The farm is located at latitude 31 °04'02.4" N and longitude 30 °31'42.19" E. The local climate is temperate-tropic humid with summer rains and with an annual average rainfall of 22 mm and mean annual temperature between 14 and 28 °C.

2.1. Moringa oleifera planting and preparation

Viable, clean and disease free *M. oleifera* seeds were obtained from The Egyptian Association of Moringa (National Research Centre, Egypt), and planted in density 100,000–150,000 seeds per ha. Before sowing, seeds were soaked in water for 24 h then kept in dark for 24 h for scarification and better germination. The land was irrigated biweekly with 1800 m^3 water ha^{-1} $month^{-1}$. Before starting the experiment, a uniformity cut was carried out 65 days after seeding, when plants reached a height of 65–70 cm (5–7 mm cutting height). Usually, *M. oleifera* is then cut after 40 days of regrowth resulting in 9 harvests per year and yielding 70–80 tonnes of fresh biomass ha^{-1} $year^{-1}$ (~23 tonnes DM ha^{-1} $year^{-1}$). For this particular experiment, *Moringa* biomass (composed of leaves and thin twigs, branches and stems) was harvested in a different way following a cut-and-carry approach so that the amount of *Moringa* biomass required to feed the goats was collected daily from the field every morning, mixed with the diet and immediately offered to the goats. The material collected was always from 40 (±5) days aftermaths. Additionally, *Moringa* material was sampled daily, composited weekly and dried at 60 °C in a forced-air oven for 48 h and stored for later chemical analysis.

2.2. Goats, feeding and experimental design

Sixteen lactating Anglo-Nubian goats (36.2 ± 0.7 kg of BW) were randomly assigned to four experimental groups. The experimental design was a quadruplicated 4 × 4 Latin square, with four treatments, four periods and four goats per treatment within each period (resulting in 16 replicates per treatment for the whole experiment). The four experimental treatments were randomly assigned to the four groups in the first period. The goats were housed individually in tie stalls with free access to water and fed on the experimental diets to meet their nutrient requirements according to NRC (2007) recommendations plus a 10% margin.

The basal diet fed to the goats contained 400 g of Egyptian berseem clover (*Trifolium alexandrinum*), 300 g of crushed yellow corn, 80 g of wheat bran and 20 g of minerals and vitamins per kg total mixed ration (DM basis). In the control diet (M0), the protein source was sesame meal included at 200 g/kg DM. In the other experimental diets, 50%, 75% or 100% of the sesame meal was replaced with MLM, by including 100 (M 10), 150 (M15) or 200 (M20) g of MLM per kg diet (on DM basis). Diets were fed to each goat individually at 08:00 and 16:00 h in two equal portions. Feed samples of berseem clover, concentrates mixture and MLM were taken daily, composited weekly and dried at 60 °C in a forced-air oven for 48 h and stored for later chemical analysis. The ingredient and nutrient contents of the four diets are in Table 1.

Each experimental period lasted 22 days; 15 days of adaptation to the new diet, and 7 days for measurements (feed intake, milk yield) and sample collection (sampling of feed and orts, faeces, ruminal fluid, blood, milk). Feed intake (recorded daily by weighing the offered diets and refusals from the previous day) and milk yield were measured daily. Faecal grab samples were collected twice daily at 07:00 and 15:00 h, dried at 60 °C in a forced-air oven for 48 h and pooled by goat within period. Acid insoluble ash was used as an internal indigestibility marker, and coefficients of digestion calculated according to Ferret et al. (1999).