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Effect of feeding lactating cows with ensiled mixture of *Moringa oleifera*, wheat hay and molasses, on digestibility and efficiency of milk production

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ABSTRACT

Moringa oleifera Lam. (MO) seedlings, sown at high density on June 2014 and grown under irrigation in Israel, were harvested at 45 d intervals to yield a total biomass of 35 t dry matter (DM) per ha. Based on a preliminary study in glass-silos, fresh harvested MO from the 2nd harvest was mixed with chopped wheat hay and sugar cane molasses at a ratio, of 370:540:90 on DM basis, respectively, and ensiled in 40 pressed bales (700 kg each) wrapped with stretch polyethylene film. This silage was included in the total mixed ration (TMR) of lactating cows at a level of 180 g/kg DM as wheat silage and hay substitute. Performance and digestion experiment was conducted with two groups of 21 milking cows each, fed individually, either the MO TMR or the control ration. Voluntary DM intake of cows, fed the control TMR, tended to be 1.22% higher than that of the MO-fed cows ($p = 0.09$). *In vivo* digestibility of DM, neutral detergent fiber (NDF), cellulose, hemicelluloses and crude protein were higher in the control cows compared with the MO-fed group. Notwithstanding, higher yields of milk and 4% fat corrected milk (FCM) by 1.91% and 4.26%, respectively, were observed in the MO-fed cows. Milk fat content was 2.34% higher and milk protein content 2.28% lower in the MO-fed cows than in their control counterparts. This was reflected in a 2.37% higher energy corrected milk (ECM) yield and 3.27% increase in production efficiency (kg ECM/kg DM intake) of the MO-fed cows compared with the control ones. Milk of the MO-fed cows was also characterized by 20% more anti-oxidative activity than that of the control cows. Body weight gain, however, was similar in both groups. It is therefore suggested to ensile mixture of MO with soy hulls or corn grains as higher digestible solid additive for feeding lactating dairy cows.

Abbreviations: ADF, acid detergent fiber; ADL, acid detergent lignin; BW, body weight; CP, crude protein; DM, dry matter; DMI, dry matter intake; ECM, energy corrected milk; EE, ether extract; EGCG, equivalent of epicatechin galate; FCM, 4% fat corrected milk; IVDMD, *in-vitro* dry matter digestibility; LDCL, luminol-dependent chemiluminescence; MO, *Moringa oleifera*; NDF, neutral detergent fiber; RFI, residual feed intake; TMR, total mixed ration.

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1. Introduction

Moringa oleifera Lam. (MO) is a tropical tree reported to have nutritional, therapeutic and prophylactic properties (Reyes-Sanchez et al., 2006; Moyo et al., 2010). MO originated from the Indian subcontinent, and later became naturalized in tropical and subtropical areas around the world. It is known to produce high leaf mass which is a potential high quality forage source for ruminants (Foidl et al., 2001; Sanchez-Machado et al., 2010). There are several advantages of using MO foliage as ruminants feed: It is drought resistance and has the ability to grow on poor soils (Foidl et al., 2001); It produces high leaf mass within a short period, and being perennial in nature, it can be harvested several times in the same growing season (Mendieta-Araica et al., 2011a,b); MO leaves are characterized by high crude protein content, adequate amino acid profile, high level of vitamins A, B, and C (Sanchez-Machado et al., 2010; Mendieta-Araica et al., 2011a; Sultana et al., 2015), and high amounts of polyphenols resulting in elevated antioxidative activity (Verma et al., 2009). Moreover, MO leaves can be fed fresh or dried, and after drying can be stored for long periods without deterioration in nutritive value (Foidl et al., 2001).

Several research studies examined the effects of using fresh or dried hand-cut MO foliage as supplement or substitute for local tropical forage or concentrates in the rations of lactating ruminants. Studies with low producing cows showed increase in milk yield in response to feeding dried or fresh leaves and soft twigs of MO supplement (Reyes-Sanchez et al., 2006; Mendieta-Araica et al., 2011a). Studies with lactating goats also showed an increase in milk yield in response to feeding MO leaves as a sesame or concentrate replacer (Sultana et al., 2015).

Despite the great potential of using MO leaves as high quality animal feed, its global commercial use has been restricted only to small farm holders leaning on hand-cut and not on modern machinery-based forage producers. The reasons for this restricted exploration are: MO is a fast growing tree producing a thick trunk and branches that create problems for commercial machinery-based harvesters (*e.g.* forage harvester or forage combine), routinely used in the forage production industry; MO leaves are characterized by high moisture content (150–200 g/kg DM) and therefore became moldy during direct ensiling, and needed a week of wilting in the field before successful ensiling (Cohen-Zinder et al., submitted for publication).

To overcome these obstacles, a new genetic variety of *M. oleifera* was developed by Dr. Yiftach Vaknin (ARO, Israel) during 10 years of selective breeding of MO germplasm acquired from India and Western Africa. This new MO variety was grown for the first time in the Mediterranean area at a high sowing density (160,000 seeds/Ha) under drip-irrigation, to produce forage, which was harvested at intervals of 45 d (four harvests/year between July to November) to yield a total forage mass of 35 t DM per ha. However, the residual trunk and thick branches left in the field after each harvest (at 20 cm height above previous harvest), interfered physically with direct-wilting of the fresh high moisture forage (180–200 g/kg DM) in the field, and dictated immediate evacuation of the fresh forage mass. A previous study that used pre-wilted (a week in the field) MO silage as forage source for lactating cows (at a level of 130 g/kg of TMR DM) resulted in an increase in milk production and milk antioxidative activity (Cohen-Zinder et al., submitted for publication). However, commercial harvests at intervals of 45 d precludes wilting for a week in the field, and dictates either fast drying of the fresh MO forage outside the field to avoid its spoilage (a costly process), or direct ensiling with solid feed additives. A preliminary glass-silo study showed that direct ensiling of mixtures of fresh MO with sugar cane molasses and either chopped wheat hay or soy hulls (at DM ratio of 370:90:540, respectively) were the best combinations that ensured successful ensiling (Cohen-Zinder et al., submitted for publication). However, the effect of feeding the ensiled mixture MO + wheat hay + molasses, as a supplement to high producing lactating cows, on intake, digestibility and efficiency of milk production was never examined.

The objective of the current study was to examine the effects of feeding the new variety of MO ensiled in a mixture with wheat hay and molasses, at a ratio on DM basis of 370:540:90, respectively, as substitute for wheat silage and hay in dairy cow ration, on: intake, digestibility, milk yield, milk composition, milk production efficiency, and milk anti-oxidative activity.

2. Materials and methods

2.1. Growth conditions of M. oleifera and its ensiling

The optimal agronomical growth conditions for the new MO variety, used as a forage crop in this study, were determined in a preliminary study (Cohen-Zinder et al., submitted for publication). Seeds of the new MO variety were sown on June 15, 2014 at density of 160,000 seeds/Ha, in a 2-ha commercial field in Eden Farm, Israel (longitude: 35° E, latitude: 32° N). The plants were drip-irrigated every week, up to sum of 800 mm during the growth season (June to November). Four mechanical harvests were conducted at 45 d intervals, at 20-cm stubble height in first cut, and additional 7-cm above each of the three following cuts. In each harvest, the MO forage (including leaves, soft twigs and thin branches) was harvested and chopped to at least 2- to 3-cm particle size using a John Deere combine harvester (9660 STS; John Deere, Moline, IL), loaded directly into trucks, delivered to Nahalal Feeding Center (29 miles distance) and weighed before ensiling. Forage yield of the entire field summarizing the four harvests of 2014 was 35 t DM/ha.

A preliminary experiment showed that direct ensiling of a mixtures of fresh MO with sugar cane molasses and chopped wheat hay or soy hulls (at DM ratio of 370:90:540 g/kg, respectively) were the best combinations that ensured successful ensiling expressed in less than 50 g/kg DM loss, low silage pH (4.0) and above 300 g/kg DM content (Cohen-Zinder et al.,

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