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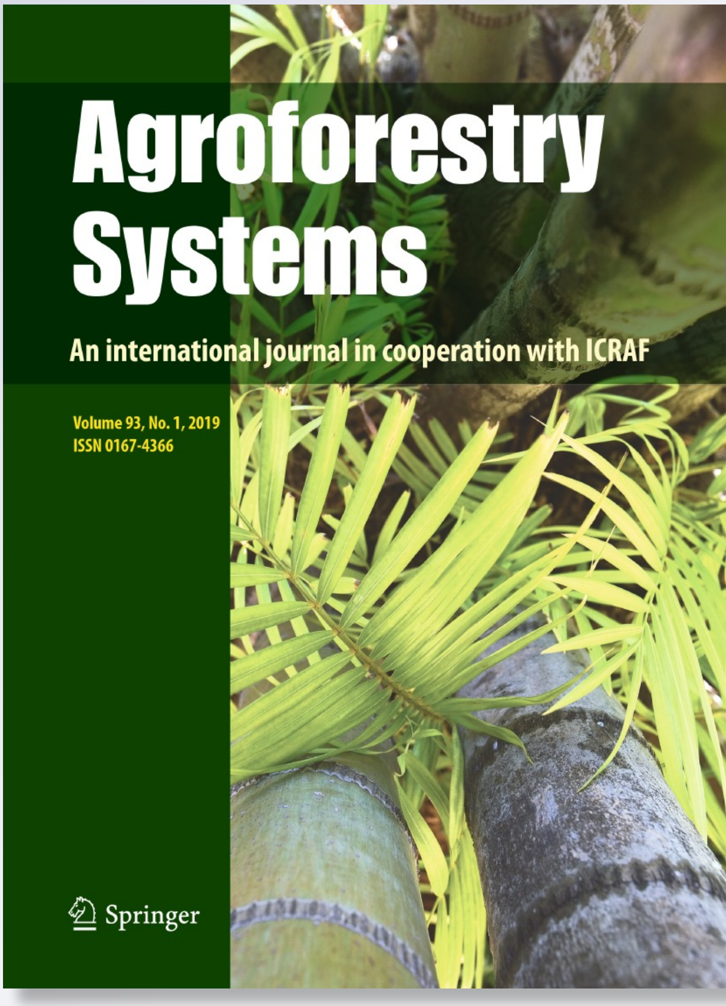

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Nutritive utilization of *Moringa oleifera* tree stalks treated with fungi and yeast to replace clover hay in growing lambs

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Abstract Twenty four Barki lambs with an average body weight of 20.7 ± 0.17 kg were used in a complete randomized design to evaluate the effects of replacing clover (*Trifolium alexandrinum* L) hay as a traditional basal diet (C) with moringa tree stalks (MS) treated with fungi (*Trichoderma reesei*) (MF) and yeast (*Saccharomyces cervisiae*) (MY) under solid-state fermentation on nitrogen and water metabolism, rumen fermentation and economic efficiency of feeds. Lambs were divided into three groups each with eight lambs depending on their live weight. Concentrate feed mixture was similar for all groups and was offered at 2% of live weight with the basal roughage offered ad libitum. The results show that the rations had significant effects ($P < 0.05$) on DM, crude protein and nitrogen free extract digestibility. Percentage total digestible nutrients was not affected ($P < 0.05$) by the experimental rations and the values ranged between 0.62 and 0.64. The MY ration had the highest ($P < 0.05$) digestible crude protein followed by C and MF. The roughage intake expressed as a percentage of total feed intake for MF and MY groups were higher by 4 and 2%, respectively compared to the control group. Average daily gains were 173, 139 and 146 g/head/day, for C, MF and MY groups, respectively. Average dressing percentages based on either fasting weight or empty weight were not affected by the experimental rations. There were no differences ($P < 0.05$) among groups in N and water balance. Rumen NH_3-N concentrations for the MF and MY groups peaked ($P < 0.05$) at 3 h post feeding whereas for the control it peaked at 6 h post feeding. Rumen TVFA's concentrations for all treatments increased gradually from zero to 6 h post-feeding. MY diet recorded the highest ($P < 0.05$) economical feed efficiency compared with MF and control diet. These results suggest that treatment of moringa stalks with S. *cerevisiae* for 21 days in a solid-state fermentation system improved its nutritive value and is more suitable for practical feeding in sheep rations.

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Keywords Moringa stalks · Sheep · Intake · Growth · Digestibility · Fermentation · Carcass

Abbreviations

CFM	Concentrate feed mixture
CW	Carcass weight
EW	Empty weight
FCR	Feed conversion ratio
MS	Moringa stalks

Introduction

Egypt has approximately 10.3 million equivalent animal unit, which requires about 44.3 million tons of feed dry matter (DM) to sustain present level of productivity (Kewan and Khattab 2016). However, as per Ministry of Agriculture and Land Reclamation (MALR 2013) estimates, only 29.9 million tons of feed DM is available. Furthermore, the deteriorating animal health and their sustainability could also pose a potential threat for human existence and their livelihood. This necessitates the use of alternative options such as agricultural crop residues and grasses (lignocellulosic biomass) as feed sources.

Fibrous agricultural by-products as feed for ruminant livestock are plentiful, but their nutritive value is limited by their high fiber, low protein content and low digestibility, factors that limit feed intake (Gebregiorgis et al. 2012). Consequently, the majority of these by-products are returned to the land as crop residues shortly after harvest and not used as animal feed (Graminha et al. 2008). The smallholder livestock farmers are therefore limited to use of clover hay as conventional feed due to unavailability and high cost of alternative feeds. To alleviate the problems associated with the lack of such feeds, there is need to look for alternative sources that farmers can generate at their farm without incurring additional costs. Use of by-products in animal diets could help in reducing the shortage of animal feeds and subsequently increase milk and meat production.

Moringa (*Moringa oleifera*) is a non-leguminous multipurpose tree. Its leaves contain between 257 and 261 g/kg DM crude protein (Sultana et al. 2015) and negligible amounts of anti-nutritive compound. Tannins and phytates in moringa are 12 and 21 g/kg of DM, respectively and total polyphenols and condensed tannins are higher in moringa at 2.55 and 1.7%, respectively than berseem forage at 1.25 and 0.40%, respectively (Khalel et al. 2014). It is worth noting that, at low concentrations simple phenols do not produce any adverse effects when consumed by animals (Khalel et al. 2014). These polyphenols have been reported to have multiple beneficial effects that include antioxidant activity, anti-inflammatory action, inhibition of platelets aggregation, antimicrobial and antitumor activities (Thurber and Fahey 2009). Condensed tannins were 1.75% for moringa versus 0.40% for berseem (Khalel et al. 2014). Comparable value for condensed tannins was 1.4% for fresh moringa foliage (Moyo et al. 2011). However, drying was reported to reduce condensed tannins by 15–30% relative to fresh plant (Vitti et al. 2005). *M. oleifera* forage could be used in diets up to 30% incorporation to substitute for soybean meal in small ruminant production (Best et al. 2017) or in vitro (Elghandour et al., 2017). Moringa stalks are a good example of a crop residue that arises from the harvesting of *Moringa oleifera* Lamarck leaves, and their nutritive values has been evaluated by Debela and Tolera (2013).

Various methods, including physical, chemical and/or biological treatment (Sarnklong et al., 2010), have been developed with the aim of increasing the digestibility of straw. Biological treatments of lignocellulosic substrates include cultivation with specific fungi capable of producing a spectrum of lignin and cellulose-degrading enzymes during solid-state fermentation. The effects of biological treatment on improving the nutritive value of fibrous forage have been assessed, but conclusions have been variable due to inconsistent treatment outcomes (Permana et al. 2004). In Egypt, treating the available low quality residues with microbial cultures and their effects on growth performance and feed utilization by livestock have been investigated (Khalel et al. 2014). Our previous study on ensiling of moringa stalks (MS) with bacteria, fungus and yeast culture in a solid state fermentation system for 21 days before feeding it to adult sheep concluded that quality in terms of palatability and nutritional value of MS as a sole roughage for ruminants could easily be improved by treating it with fungi or yeast.

Therefore, the objective of the current study was to evaluate the effects of replacing clover hay as a traditional basal diet (C) with moringa stalks (MS) treated with fungi (*Trichoderma reesei*) (MF) and yeast (*Saccharomyces cervisiae*) (MY) under solid-state fermentation on nitrogen and water metabolism, rumen fermentation and economic efficiency of feeds in growing lambs.

Materials and methods

The study was conducted at the Maryout Research Station farm (located 35 km South West of Alexandria, Latitude 31.02°N, Longitude 29.80 °C), Desert Research Center, Egypt. The experiment extended for 140 days and the animals were handled and cared for in accordance with the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS 1999).

Animals, diets and management

Twenty-four male Barki lambs with an average body weight of 20.7 ± 0.17 kg and about three months of age were used in a complete randomized design experiment. Lambs were divided into three groups each with eight lambs depending on their live weight. Lambs were housed individually in shaded cages (with area 2.0 m^2) and weighed at the beginning of the experiment and thereafter at two-week intervals up to the end of the experiment.

Three rations were used to feed the growing Barki lambs, i.e. concentrate feed mixture (CFM) plus clover hay as the control ration; C, CFM plus moringa stalks treated with fungus *Trichoderma reesei*; MF and CFM plus moringa stalks treated with yeast *Saccharomyces cervisiae;* MY. The CFM was offered to all groups at 2% of the live weight of each animal and the amount offered revised biweekly depending on the live weight. The ingredient used for the CFM included 35% un-decorticated cotton seed cake; 33% wheat bran; 22% yellow corn; 4% rice bran, 3% molasses, 1% salt and 2% limestone. The chemical composition (g/kg DM) of the experimental rations and treated moringa stalks is presented in Table 1. Each type of roughage was offered ad libitum and feed refusal, if any, were collected daily and weighed to assess intake before new feed was offered. Clean, fresh water was offered free choice through the experiment.

The facultative microbial strains used for treating moringa stalks were the fungus (*Trichoderma reesei*) and yeast culture (*Saccharomyces cerevisiae*).

Table 1 Chemical composition (g/kg DM) of the experimental rations including biological treated moringa stalks fed to growing Barki lambs

Items	Feed ingredients[a]				Experimental rations[b]		
	CFM[a]	Hay	MSF	MSY	C	MF	MY
Moisture (g/kg fresh weight)	91	128	115	106	129	97.7	94.2
Organic matter	866	857	901	894	869	874	879
Crude protein	138	118	109	143	124	130	142
Ether extract	21.3	19.4	29.6	23.9	17.1	23.8	22.1
Nitrogen free extract	500	455	418	395	470	481	481
Neutral detergent fiber	464	388	658	612	434	547	525
Acid detergent fiber	251	215	487	467	237	352	340
Acid detergent lignin	85.7	54.2	67.8	69.9	73.4	78.0	79.2
Cellulose	165	161	419	397	163	274	261
Hemicellulose	213	173	171	144	197	195	185
Market price (US$/ton)	305.8	220.2	79.5	79.5	273	211	214

One United States Dollar (US$) = 16.35 Egyptian pound (LE)

[a]*CFM* concentrate feed mixture contained un-decorticated cotton seed cake 35%; wheat bran 33%; yellow corn 22%; rice bran 4%, molasses 3%, salt 1% and limestone 2%. C. clover hay; *MSF* moringa stalks treated with *Trichoderma reesei*; MSY: moringa stalks treated with *Saccharomyces cervisiae*

[b]*C* Control—CFM plus Clover hay, *MF* CFM plus moringa stalks treated with *Trichoderma reesei*, *MY* CFM plus moringa stalks treated with *Saccharomyces cervisiae*

Microbiological studies were carried out at the Microbiology Laboratory, Desert Research Center, Al-Mattaria, Cairo, Egypt. During the preparation of the growth cultures, each strain of micro-organism was maintained in a special medium; Czabek Dox agar for *T. reesei* (Oxoid 1982) and yeast extract malt agar for *S. cervisiae* (Pridham et al. 1958). Two medium cultures were prepared and used to inoculate a sterilized broth medium. The inoculated medium (cultures) was incubated at 30 °C for 7 days for the fungus and 3 days for yeast. Each one of the previous growth cultures (12% of residual weight; v/w) were diluted with tap water and then added to the chopped residues to make final moisture around 60%. All were mixed well and then bagged and compressed in clean 50-kg plastic bags and sealed. The bags were then incubated in a chamber for 21 days at room temperature. At the end of the incubation period, the treated materials were sun-dried to stop further microbial activity and dried to about 10% moisture content. These were stored until used in feeding trials.

Digestibility, nitrogen and water metabolism trials

Four lambs were randomly chosen from each group for the in vivo digestibility trial to evaluate the nutritive value of the experimental rations. Lambs were placed in metabolic cages (1.6 m × 0.53 m) for the complete separation of feces and urine. The trial involved 15 days for adaptation followed by 5 days for total collection of feed, fecal and urine.

Sampling of rumen liquor

Rumen liquor samples were collected by stomach tube from three animals in each group a day before the end of the digestibility trial. The samples were taken at 0, 3 and 6 h post-feeding. The rumen samples were filtered through two layers of cheesecloth and immediately the pH was measured. A few drops of 0.1 N HCl was added to the strained rumen liquor in plastic bottles and stored in a deep freeze (− 20 °C) till analysis for ammonia nitrogen (NH_3-N) and total volatile fatty acids (TVFA).

Slaughtering and carcass characteristics

At the end of the experiment, three lambs from each group were slaughtered after an overnight fast. After complete bleeding and removal of the head, feet and pelt, the offals and thoracic and abdominal organs were removed and weighted. The contents of the digestive tract were removed and their weight was subtracted from the slaughter live weight to obtain the empty body weight (EW). Dressing percentage was estimated as the percentage of carcass weight (CW) relative to the EW and as a percentage of the hot carcass relative to the EW. The 9–10–11th rib section was removed from the carcass of each lamb and stored in sealed polyethylene bags in a fridge until analysis. The ribs were dissected into their physical composition; lean (L), fat (F) and bone (B). The area of *Longissimus dorsi* (LD) over the ninth rib was measured by a Planimeter and the back fat thickness was determined at the deepest point. Fat thickness was measured on the ninth rib.

Laboratory analysis

Chemical composition of feeds, feces and urine

The samples of feed, feces and urine were analyzed for proximate analysis according to AOAC (2000), dry matter (DM; method 930.15), crude ether extract (EE; method 954.02), crude protein (CP; method (Kjeldhal) 955.04) and ash (method 942.05). Cell wall constituents (NDF, ADF and ADL) were determined according to Van Soest et al. (1991) using the automated ANKOM fiber analyzer. Cellulose and hemicelluloses were calculated by difference.

Rumen pH, ammonia-N and total volatile fatty acids

The pH of filtered rumen liquor samples were recorded using Beckman pH meter just after collection. The stored strained rumen liquor samples were thawed at room temperature and then analyzed for ammonia nitrogen (NH_3-N) using Markham micro-distillation apparatus (Markham 1942) and total volatile fatty acids (TVFA) according to El-Shazly et al. (1963).

Chemical composition for rib-eye muscle

Boneless 9–10–11th ribs (lean and fat) of each carcass were minced and subsamples were analyzed according to AOAC (2000) for ash. Chemical analysis (moisture, protein, fat and collagen) of the L. dorsi samples were determined using Food Scan^{TM} Pro Meat Analyzer

Table 2 Nutrient digestibility and nutritive values (g digested/g ingested) of the experimental rations fed to growing Barki lambs

Items	Experimental rations[1]			SEM[2]	P value[3]
	C	MF	MY		
Nutrient digestibility					
Dry matter	0.71[a]	0.68[b]	0.65[b]	0.080	0.004
Crude protein	0.75[a]	0.69[b]	0.77[a]	0.103	0.001
Crude fiber	0.68	0.66	0.69	0.071	0.237
Ether extract	0.79	0.80	0.79	0.043	0.228
Nitrogen free extract	0.72[a]	0.71[a]	0.64.[b]	0.136	0.003
Nutritive values					
TDN	0.64	0.64	0.62	0.044	0.254
DCP	0.098[b]	0.087[c]	0.11[a]	0.025	0.001

TDN total digestible nutrients, *DCP* digestible crude protein

[1]*C* control—CFM plus Clover hay, *MF* CFM plus moringa stalks treated with *Trichoderma reesei*, *MY* CFM plus moringa stalks treated with *Saccharomyces cervisiae*

[2]Standard error of mean

[3]Probability value

[a,b,c]Means in the same row with different superscripts are significantly different ($P < 0.05$)

(Foss Analytical A/S Model 78810, Denmark), according to the manufacturer's instructions.

Economic efficiency of feeds

Economic efficiency expressed as the ratio between the price of total live weight gain and the price of feeds consumed was estimated in Egypt pounds (LE) and converted to USD (1 USD = 16.35 Egyptian pound (March 2017) per ton: concentrate feed mixture US$ 306/ton, biological treated moringa US$ 79.5/ton and clover hay US$ 220/ton. The price of one kg live weight on selling was US$ 3.06.

Statistical analysis

The data were analyzed in a completely randomized design using SPSS (2010) program version 19. The following statistical model was adopted: $Y_{ij} = \mu + T_i + e_{ij}$. Where Y_{ij} = experimental observation; μ = general mean; T_i = effect of tested ration; e_{ij} = experimental error. Treatment means were separated using the new multiple range test of Duncan (1955).

Results

Nutrients digestibility and nutritive values

The nutrient digestibility and nutritive values of the experimental rations is presented in Table 2. The DM digestibility was lower ($P < 0.05$) for moringa treated stalks rations compared to the control. The MF ration was comparable with C ration regarding NFE digestibility. However, MY ration was not different ($P < 0.05$) from the control ration with respect to CP digestibility. The EE digestibility of the basal ration were not different ($P > 0.05$). Total digestible nutrients (TDN) were not affected ($P < 0.05$) by the experimental rations. The MY ration had the highest ($P < 0.05$) digestible CP followed by C and the lowest was MF (Table 2).

Intake and growth performance

The performance and economic indicators of the experimental rations is presented in Table 3. Both the MF and MY lambs showed lower consumption of CFM relative to the control. However, the total DM intake (roughage plus CFM) was not affected by the experimental rations. The roughage intake expressed as a percentage of total feed intake was calculated for

Table 3 Performance and economic indicators of the experimental rations fed to growing Barki lambs

Items	Experimental rations[1]			SEM[2]	P value[3]
	C	MF	MY		
Lamb performance					
Initial live weight, kg	20.6	20.9	20.7	0.17	0.779
Final live weight, kg	44.8[a]	40.3[b]	41.2[b]	0.71	0.015
Total gain, kg	24.3a	19.4[b]	20.5[b]	0.61	0.001
Average daily gain, g/day	173[a]	139[b]	146[b]	4.39	0.001
Total DM feed intake, g/head/d	1074	1069	1052	13.80	0.806
CFM intake, g DM/head/day	654[a]	611[b]	619[ab]	8.49	0.082
Roughage intake, g DM/head/day	420	458	433	7.61	0.113
Roughage intake, g DM/100 g DM of total ration intake	39.1[c]	42.7[a]	41.2[b]	0.380	0.001
Roughage intake, kg DM/100 kg BW	1.29[c]	1.50[a]	1.40[b]	0.022	0.001
FCR[4], kg DM intake/kg gain	6.20[c]	7.77[a]	7.22[b]	0.155	0.001
Economic indicators[5]					
Cost of daily fresh feed, US$	0.33[a]	0.25[b]	0.25[b]	0.009	0.001
Value of daily gain, US$/head	0.53[a]	0.42[b]	0.47[b]	0.013	0.001
Daily return, US$/head	0.20	0.17	0.20	0.007	0.245
Economical feed efficiency	160.1[b]	168.1[b]	179.0[a]	2.35	0.001
Relative economic efficiency	100	105	112	–	–

[1]*C* control—CFM plus Clover hay, *MF* CFM plus moringa stalks treated with *Trichoderma reesei*, *MY* CFM plus moringa stalks treated with *Saccharomyces cervisiae*

[2]Standard error of mean

[3]Probability value

[4]*FCR* feed conversion ratio

[5]Calculated according to the price of year 2017 where United States Dollar (US$) = 16.35 LE Egyptian Pound

[a,b,c]Means in the same row with different superscripts are significantly different ($P < 0.05$)

the MF and MY lambs and were higher by 3.6 and 2.1%, respectively than control. Moreover, roughage intake as a percentage of live weight was 0.21 and 0.11% higher for MF and MY lambs, respectively compared to control. Control lambs had higher ($P < 0.05$) final body weight than MF and MY lambs. The MY lambs had 84% daily gain of control lambs, while the MF lambs had 80%. The economic efficiency was higher with the MY diet compared with control and MF diets (Table 3).

Nitrogen and water metabolism

Nitrogen and water utilization during the digestibility trial is presented in Table 4. Roughage N intake was higher ($P < 0.05$) in MY group followed by MF and C lambs which did not differ. MF lambs showed the highest ($P < 0.05$) fecal N output. Nitrogen retention was positive for all groups and there were no differences ($P > 0.05$) among groups, but C showed the highest values followed by MY and then the MF lambs. The type of roughage provided significant ($P < 0.05$) affected the amount of water consumed by the lambs. The highest free water intake was with C followed by MF and MY which did not differ. Water balance was not affected by the experimental rations (Table 4).

Rumen function parameters

Mean rumen pH, NH_3-N and total VFA concentrations in the rumen are presented in Table 5. No differences ($P > 0.05$) were observed among experimental diets on ruminal pH. Feeding lambs on the treated rations

Table 4 Nitrogen and water utilization of the experimental rations fed to growing lambs during digestibility trials

Items	Experimental rations[1]			SEM[2]	P value[3]
	C	MF	MY		
Nitrogen utilization, g/head/day					
CFM- N intake	17.7	16.9	17.2	0.25	0.437
Roughage-N intake	9.30[b]	9.70[b]	12.1[a]	0.41	0.004
Fecal N, FN	6.66[b]	8.13[a]	6.78[b]	0.23	0.001
Urinary N, UN	12.7[b]	11.8[b]	15.4[a]	0.57	0.007
N balance, NB	7.69	6.71	7.18	0.27	0.399
Water utilization, g/kg $BW^{0.82}$/day					
Free water intake	137[a]	108[b]	105[b]	5.81	0.019
CFM water intake	3.87	3.83	3.85	0.010	0.268
Roughage water intake	3.50[b]	3.63[a]	3.11[c]	0.069	0.002
Metabolic water	24.1[b]	25.5[a]	24.3[ab]	0.27	0.068
Total water intake	169[a]	141[b]	136[b]	5.69	0.017
Fecal water, FW	26.4[a]	19.7[b]	17.8[b]	1.25	0.001
Urinary water, UW	39.3	38.9	35.8	1.14	0.442
Water balance, WB	103	82.4	82.1	4.58	0.081

[1] *C* control—CFM plus Clover hay, *MF* CFM plus moringa stalks treated with *Trichoderma reesei*, *MY* CFM plus moringa stalks treated with *Saccharomyces cervisiae*

[2] Standard error of mean

[3] Probability value

[a,b,c] Means in the same row with different superscripts are significantly different ($P < 0.05$)

showed higher ($P < 0.05$) rumen NH_3-N concentrations at 3 h after feeding compared with at zero time and 6 h after feeding. The C lambs exhibited the peak rumen NH_3-N concentrations at 6 h post-feeding. All the experimental rations showed gradual increased ($P < 0.05$) of rumen TVFA's from zero time up to 6 h post-feeding but these did not differ (Table 5).

Carcass characteristics

Dressing percentage, trimmings, offals and carcass fat is presented in Table 6. Lambs receiving the C and MY rations showed comparable values for FW and HCW. The MF and MY lambs had lower ($P < 0.05$) EW than C lambs. The total trimmings (head, feet, pelt, blood and gastro-intestinal tract contents was not affected by the experimental rations, while the offals of carcass include heart, liver, kidney, spleen, lungs-trachea, testicles, and empty gastro-intestinal tract were higher ($P < 0.05$) in treated moringa stalks (MY and MF) than C lambs. Total carcass fat (including visceral fat, kidney fat and tail) was higher ($P < 0.05$) in C lambs compared to the MF and MY lambs (Table 6).

Physical components and chemical analysis of rib-eye muscle (LD) is presented in Table 7. The control ration had higher ($P < 0.05$) L.D. muscle area, fat thickness, and percentage of fat and bone components than MY and MF lambs. The MY and MF lambs had the highest ($P < 0.05$) lean percentage compared to the control. An opposite trend was observed for fat percentage (g/100 g fresh weight L.D.) where the C lambs were higher followed by MF group and then MY lambs (Table 7).

Discussion

Nutrient digestibility and nutritive value

Biological treatment of moringa stalks has been shown to increase digestibility for most substrates with high CP content, besides ensuring more fermentable substrates in the rumen (Mahesh and Mohini 2013). The main hindrance to the biological break down of lignocellulose is the physical protection of cellulose by lignin against cellulolytic enzymes. Consequently, the biological treatments of moringa stalks may improve the accessibility of cellulosic fractions and therefore improve digestibility (Yu et al. 2009). Ward and Perry (1982) found an improved digestibility of DM and nitrogen free extract of corn cobs treated with *Trichoderma viride* in lambs. Similarly, Omer et al. (2012) showed that biologically treated corn stalks (using *Trichoderma ressi*) could completely replace clover hay in the ration of growing sheep which was

Table 5 Mean pH, ammonia–nitrogen and total volatile fatty acid concentrations in the rumen of sheep fed the experimental rations

Items	Sampling time (h)	Experimental rations[1]			SEM[2]	P value[3]
		C	MF	MY		
Rumen pH value	0	7.27	7.03	6.87	0.18	0.710
	3	6.80	6.73	6.93	0.052	0.317
	6	6.90	6.73	6.83	0.083	0.766
NH_3-N, mg/dl	0	23.8	26.8	25.8	0.92	0.439
	3	36.8[b]	38.5[ab]	43.7[a]	0.358	0.004
	6	42.2[a]	37.6[b]	36.5[b]	0.298	0.001
TVFA's, meq/dl	0	8.58	7.78	7.62	0.197	0.078
	3	10.5	11.7	11.3	0.24	0.086
	6	13.3	12.6	12.9	0.43	0.873

[1]*C* control—CFM plus Clover hay, *MF* CFM plus moringa stalks treated with *Trichoderma reesei*, *MY* CFM plus moringa stalks treated with *Saccharomyces cervisiae*

[2]Standard error of mean

[3]Probability value

[a,b,c]Means in the same row with different superscripts are significantly different ($P < 0.05$)

Table 6 Dressing percentage, trimmings, offals and carcass fat for lambs fed the experimental rations

Items	Experimental rations[1]			SEM[2]	P value[3]
	C	MF	MY		
Fasting weight; FW, kg	41.8[a]	34.1[b]	37.4[ab]	1.41	0.048
Empty weight; EW, kg	34.4[a]	26.7[b]	29.0[b]	1.28	0.010
Hot carcass weight, HCW, kg	19.5[a]	15.1[b]	16.4[ab]	0.79	0.031
Dressing percentage					
g/kg FW	466	442	438	0.59	0.091
g/kg EW	567	565	565	0.51	0.985
Total trimmings					
g/kg FW	407	401	400	0.56	0.890
g/kg EW	495	513	515	0.95	0.710
Total internal offals, TIO					
g/kg FW	126[b]	157[a]	163[a]	0.72	0.040
g/kg EW	152[b]	201[a]	210[a]	1.00	0.008
Total carcass fat,					
g/kg FW	36.2[a]	19.8[b]	21.7[b]	0.28	0.003
g/kg EW	44.1[a]	25.3[b]	27.9[b]	0.33	0.007
g/kg CW	77.7[a]	44.7[b]	49.2[b]	0.56	0.004

[1]*C* control—CFM plus Clover hay, *MF* CFM plus moringa stalks treated with *Trichoderma reesei*, *MY* CFM plus moringa stalks treated with *Saccharomyces cervisiae*

[2]Standard error of mean

[3]Probability value

[a,b,c]Means in the same row with different superscripts are significantly different ($P < 0.05$)

evidenced by a favorable increase in DMI, and an improvement in the digestibility of all nutrients with higher average daily gain. Bhumibhomon et al. (1988) suggested that digestion coefficient of both crude fiber and CP improved due to enzymes produced by microbes (especially amylase and protease) which were involved indirectly in the digestion of carbohydrate and protein. The improvement in digestibility might also be due to solubilization or increased biodegradability of cell wall components (Agosin et al. 1986). The insignificant difference in CF digestibility among treatment groups may be because the biological treatments increased availability of

Table 7 Physical components and chemical analysis of rib-eye muscle (LD) of Barki lambs' carcass

Items	Experimental rations[1]			SEM[2]	P value[3]
	C	MF	MY		
Physical components of L.D. muscle					
L.D. muscle area, cm^2	27.5[a]	16.0[c]	19.6[b]	1.78	0.001
Fat thickness, cm	5.23[a]	1.89[b]	2.17[b]	0.55	0.001
Lean, g/100 g fresh weight of L.D.	42.4[b]	54.3[ab]	61.7[a]	3.34	0.025
Fat, g/100 g fresh weight of L.D.	26.6[a]	14.6[b]	10.2[c]	2.49	0.001
Bone, g/100 g fresh weight of L.D.	31.0	27.6	29.7	1.42	0.684
Chemical analysis of L.D. muscle					
Dry matter, g/kg fresh weight of L.D.	342	333	347	0.65	0.741
Crude protein, g/kg DM of L.D.	628	644	646	1.08	0.799
Ether extract, g/kg DM of L.D.	271	274	273	0.78	0.988
Ash, g/kg DM of L.D.	32.9	34.0	36.0	0.17	0.810
Collagen, g/kg DM of L.D.	65.5[a]	45.0[ab]	40.4[b]	0.51	0.072

[1]*C* control—CFM plus Clover hay, *MF* CFM plus moringa stalks treated with *Trichoderma reesei*, *MY* CFM plus moringa stalks treated with *Saccharomyces cervisiae*

[2]Standard error of mean

[3]Probability value

[a,b,c]Means in the same row with different superscripts are significantly different ($P < 0.05$)

digestible cellulose from acid detergent fiber fraction in moringa stalks to the animals (Nsereko et al. 2002).

Intake and performance of growing Barki Lambs

The highest DMI was recorded for MF probably due to the optimum level of fiber and a favorable combination of forage to concentrate ratio that improved palatability (Sultana et al. 2015). Aregheore (2002) found that feeding *M. oleifera* at 20 and 50% of the total daily forage intake by goats was associated with better dietary protein utilization and feed conversion than those fed Batilhi grass. Similar to our results, feed intake was numerically improved with yeast supplementation as reported by Tripathi and Karim (2011). The differences between the studies could be attributed to the basal diet, forage type and feeding strategy, because different contents of readily soluble carbohydrates in the diet affect DMI in ruminants (Cömert et al. 2015).

The results of live weight and average daily gain in the present study are in parallel with the digestibility trial results, which showed that biological treatment enhanced the digestibility of most nutrients in moringa stalks to be close to that in clover hay. The comparable values of final live weight and average daily gain between MF and MY are probably due to improved quality of moringa stalks treated with fungus or yeast which probably enhanced the utilization and the availability of essential nutrients especially protein, energy and mineral of the dietary organic matter.

Higher feed conversion in MY lambs compared to MF lambs could be explained by the beneficial effects of yeast treatment of moringa stalks, which provided stimulator factors and essential nutrient especially protein, energy, minerals and vitamins that are better utilized by sheep (Rossi et al. 2006). In addition, improvement in MY group as a result of yeast treatment may be attributed to its changes of microflora in the rumen especially the more active role of cellulolytic bacteria (Umesh-Kumar et al. 1997) and/or may be related to shifts in efficiency of fermentation by increasing ruminal propionate and decreasing acetate concentrations. Similar to our results, Omer et al. (2012) had shown that, biologically treated corn stalks (using *Trichoderma ressi*) could completely replace clover hay in the ration of growing sheep which was evidenced by a favorable increase in DMI, and an improvement in the digestibility of all nutrients and with higher average daily gain.

Economic efficiency of diets

Daily feed cost was lower by 24.2% for MF and MY, respectively compared to the control diet in agreement with Omer et al. (2012) who reported that inclusion of biological treated corn stalks in sheep rations slightly decreased total daily feeding costs of experimental rations compared to the control ration. MY diet recorded the highest ($P < 0.05$) economical feed efficiency compared with MF and control diet mainly due to its higher value of daily gain and lower cost of daily fresh feed, respectively. This result is pertinent because the replacement of a conventional high-cost ingredient, such as clover hay, for a by-product, such as biological treated moringa stalks, shows the possibility of using new ingredients in ruminant diets. Reduction in the cost of production due to replacement of clover hay with biological treated moringa stalks will increase profit and better the living standard of farmers.

Nitrogen and water metabolism

Differences in CFM-N intake may be attributed to DMI, CP intake and N concentrations of diets (Sultana et al. 2015). Fadiyimu et al. (2010) obtained an average N intake of 9.28 g/day for sheep fed various levels of *Moringa oleifera* as supplement to *Panicum maximum*. In the current study, lambs fed MY ration had the highest urine N compared with the other treatment probablly due to its high soluble protein contents, which is mainly digested in rumen resulting in higher amount of NH_3 that cannot be fully utilized by rumen microorganism and are thus lost as urea in urine (Sultana et al. 2015). The N balance in the present study did not differ and are similar (7.4 g/days) to those obtained by Rufino et al. (2013) for lambs fed diets containing soybean meal replaced with inactive dry yeast at 0 and 33% on DM basis. The positive N retention values for all treatments suggest that the protein in the diets was adequate to meet the requirement for maintenance and growth of experimental lambs (Sultana et al. 2015). Fayed et al. (2009) found that biological treatment (*T. viride* + S. *cerevisiae*) enhanced N balance through reduction of N excretion compared with group fed the control ration.

Water metabolism

The water consumption of sheep fed treated roughages has not been previously discussed in the literature. Biological treated groups had lower total water intake and fecal water compared with control group. Contrasting trends were reported by Fayed et al. (2009) in Barki lambs fed olive leaves and twigs treated with *T. viride* + S. *cerevisiae*. The differences between the results of the two studies may be attributed to the type of roughage used. The results of the present study are lower than those of sheep fed diets containing fungus treated paddy straw (Abou-Ammou et al. 2011) and for Egyptian sheep (Rahmani or Farafra) fed rations containing a new local probiotic (co-culture of two strains of fungi; *T. reesei* and *Aspergillus oryza* with dry baker's yeast; *S. cerevisiae* and the product fortified with mixture of medicinal herbs) at levels 0, 0.3, 0.4 and 0.5% of the concentrate feed mixture.

Rumen function parameters

The ruminal pH and TVFA were not affected by the experimental rations and were within the normal range. Ruminal NH_3-N in the present study of the experimental rations were higher than the threshold (5 mg/100 ml) for maximal microbial growth (Satter and Slyter 1974). The NH_3-N is a product of microbial protein degradation, of hydrolysis of the diet compounds or endogenous non-protein nitrogen and of microbial cell degradation (Merchen 1988). The ruminal NH_3-N for the MY ration peaked at 3 h post-feeding compared to the C ration which peaked at 6 h post-feeding. The MY ration contained higher soluble plant protein which led to the production of large quantities of NH_3-N in excess of the requirements of rumen microorganisms and were converted to urea in the liver and excreted in urine. This explains the higher ($P < 0.05$) urinary N and total N output for MY lambs. Marcondes et al. (2009) reported that ruminal degradability of yeast protein compared to soybean meal was 99 versus 79% implying the treated rations showed higher NH_3-N production. However, Yadov and Yadav (1988) reported that increased ruminal NH_3-N concentration might be due to the higher N intake and higher CP digestibility. Omer et al. (2012) reported that, inclusion of biologically treated corn stalks in sheep rations increased ruminal pH, NH_3-N and TVFA concentrations compared to control diet. Consistent with our results, Cömert et al. (2015) observed that NH_3-N was increased by yeast supplementation. In agreement with our findings for the group fed MY ration, Khadem et al. (2007) reported that rumen NH_3 concentration peak at 4 h post-feeding. Cömert et al. (2015) postulated that the decline in concentration of NH_3 in the rumen after 3 h post-feeding appeared to be a result of increased incorporation of NH_3 into microbial proteins, possibly because of stimulation of microbial activity.

Carcass characteristics

The present results of dressing percentage based on FW are close to those (444 g/kg FW) reported on Barki sheep by Sami and Shehata (2006) but lower than those (522 g/kg FW) reported by El-Asheeri and Hafez (2009). Abou-Ammou et al. (2011) also found that lambs fed traditional ration showed the highest ($P < 0.05$) dressing percentage (462 g/kg FW) compared with the other groups fed rations containing different percentage of fungus treated wheat straw (ranged between 426 and 435 g/kg FW).

Total trimmings and offal values were lower than those reported by Abou-Ammou et al. (2011) for sheep fed biological treated wheat straw and also differed with results reported by El-Refaey (2006) who found that edible offal weight were significantly different among the studied biological treated roughages. Total carcass fat in the present study were lower than those reported by Abou-Ammou et al. (2011) for carcass fat from sheep fed biological treated wheat straw. The opposite trend was observed with the same author's result for lean percentage.

The chemical composition of L.D. meat showed that CP and EE percentages were within the range reported in lamb meat by Abou-Ammou et al. (2011). However, lambs meat averages 75% humidity, 19% CP, 4% fat and 1% mineral matter, which is lower than values obtained in the present study, probably due to the difference in lamb strains. Collagen content was similar to those reported by Kewan (2013) in Barki lamb meat.

Conclusions

Treatment of moringa tree stalks with S. *cerevisiae* for 21 days in a solid-state fermentation system is more suitable for improving its nutritive value for practical feeding in sheep rations. However, water consumption of sheep fed diets including biological treated roughages has not been previously discussed in available literature. Further research on the influence of biological treatments on water utilization and balance in ruminant animals is therefore warranted to explore the relationship between dietary treatments and water on nutrients digestion and metabolism.

Compliance with ethical standards

Conflict of interest All authors declare that there are no present or potential conflicts of interest among the authors and other people or organizations that could inappropriately bias their work.

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