IJAS Iranian Journal of Applied Animal Science

Nutritional Value of Spent Mushroom (*Agaricus bisporus*) Compost Silage Treated with Different Level of Molasses in Sheep Feeding

Research Article

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Received on: 20 Jun 2022
Revised on: 9 Oct 2022
Accepted on: 18 Oct 2022
Online Published on: Mar 2023

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Online version is available on: www.ijas.ir

ABSTRACT

This study aimed to evaluate *in vitro* and *in vivo* the nutritional value of the spent mushroom (*Agaricus bisporus*) compost (SMC) silage treated with different levels of molasses. For this purpose, the SMC samples were treated with 0, 7.5, and 15% (dry matter basis) of molasses (SMC_0, $SMC_{7.5}$, and SMC_{15}, respectively) and ensiled over 60 days. At the end of the ensiling period, chemical composition and fermentation characteristics (including pH, NH_3, water-soluble carbohydrates (WSC) and lactic acid contents, buffering capacity (BC), and flieg point) of the silages were determined. Ruminal fermentation characteristics and total tract digestibility of the silages were determined *in vitro* (24-h and 144-h incubations) and *in vivo* (using 18 male lambs), respectively. Molasses treatment improved SMC silage fermentation characteristics by lowering pH and BC ($P<0.05$). In 24-h incubations, the gas produced over 24 h of incubation (GP_{24}), dry matter digestibility (DMD_{24}), and total volatile fatty acids were higher in $SMC_{7.5}$ and SMC_{15} than SMC_0 ($P<0.05$). In 144-h incubations, asymptotic gas production (A), dry matter and organic matter digestibility (DMD_{144} and OMD_{144}) increased, and lag time (L) decreased in the $SMC_{7.5}$ and SMC_{15} ($P<0.05$). *In vivo* digestibility of nutrients (except neutral detergent fiber (NDF)) was improved non-linearly with molasses treatment ($P<0.05$). The NDF digestibility tended to increase linearly with molasses treatment ($P=0.056$). These results revealed that ensiling spent mushroom compost with 15% molasses significantly improves its nutritional value, making it a cost-effective by-product feedstuff that can be used in ruminant diets.

KEY WORDS fermentation characteristics, *in vivo* digestibility, molasses, spent mushroom compost silage.

INTRODUCTION

Fodder scarcity is one of the major constraints for the livestock production sector in the arid and semi-arid regions of the world (Noordar *et al.* 2017). Agricultural by-products or industrial wastes can alleviate feed shortage challenges in livestock production systems in these regions and reduce diet cost by partially replacing conventional feeds in the diet of farm animals (Valizadeh and Sobhanirad, 2009). Spent mushroom compost (SMC) is the main by-products from the commercial production of edible mushrooms containing a higher CP and soluble cell-walls contents than the original lignocellulose biomass, which can be considered as a by-product feedstuff in ruminants' diet (Van Kuijk *et al.* 2015). Because of numerous beneficial effects of edible mushrooms on the human health, and in response to increasing demand of consumers for mushrooms as a mutual part of their food basket, the commercial production of mushrooms has been doubled over the last two decades attaining an annual production of 12 million tons worldwide (FAO, 2019). Spent mushroom compost (SMC) is the residual lignocellulosic waste remaining after harvesting the mushroom crop. Regarding a mass of 5 tons of SMC generated per ton of mushroom crop produced, there would

be a huge amount of SMC produced annually by the mushroom production industry that should be disposed of, resulting in environmental pollution (Lau *et al*. 2003; Uzun, 2004).

However, SMC is a lignocellulose by-product with a relatively high CP content (62.5-136 g/kg; Kwak *et al*. 2009; Kim *et al*. 2014) that can be used in ruminant diet (Okano *et al*. 2004; Okano *et al*. 2006). Previous research has indicated that the inclusion of SMC in the diet of ruminants had no negative impact on their performance and total tract digestibility at levels up to 400 g/kg DM of diet (Bakshi and Langer, 1985; Fazaeli and Masoodi, 2006). Despite containing an acceptable CP content compared with cereal straws, SMC has generally a high ash content and low palatability (78.0-548 g/kg DM; Kim *et al*. 2011), restricting its incorporation in the diet. Additionally, fresh SMC possesses a high moisture content challenging its long-term storage in the field. Hence, ensiling SMC with water-soluble carbohydrates can overcome the abovementioned restrictions; however, data on the treatment and ensilage of SMC are scarcity in the literature. There are several data in the literature on the use of soluble carbohydrates, such as molasses, for ensiling diverse agricultural wastes. In this regard, Neghabi *et al*. (2013) reported that the use of molasses improved the fermentation of *Atriplex lentiformis* silage. In another experiment, Balakhial *et al*. (2008) investigated the nutritional value of whole-crop canola silage treated with molasses. Therefore, the objectives of the present study were to prepare the SMC silage with different levels of molasses and evaluate its nutritive value using *in vitro* and *in vivo* methods.

MATERIALS AND METHODS

Silage preparation

This experiment was carried out at Animal Science Department of Bu-Ali Sina university (Research center of Abbas Abad, Hamedan). The spent mushroom (*Agaricus bisporus*) compost (SMC) was provided from a commercial mushroom farm (Sina Mushroom Farm, Hamadan, Iran). The SMC (dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) % of SMC were 28.04, 55.59, 6.46, 29.69, and 27.01%, respectively) were then divided into three equal parts and treated with 0, 7.5 and 15% (dry matter basis) of molasses and considered as the control (SMC_0), $SMC_{7.5}$ and SMC_{15} treatments, respectively. The treatments (homogeneous materials) were filled into 3 cement silos (with dimensions of 1×1×1 m) which were placed on the ground, compressed tightly, and ensiled for 60 days.

Chemical analysis and fermentation parameters of the silage

At the end of the ensiling period, the silos were opened and the silage samples were collected from different parts of the silages to give a representative sample for chemical composition analysis (6 replicate). The silage samples were then dried at 55 ˚C for 48 h and ground to pass a 1-mm sieve (Wiley mill; Thomas Scientific, Gloucester, NJ). Dry matter (DM), organic matter (OM), and crude protein (CP) content of the samples were determined according to the methods described by AOAC (1998). The neutral detergent fiber (NDF) and acid detergent fiber (ADF) content of the samples were measured as described by Mertens (2002). Sub-samples of the silages (fresh samples) were taken and subjected to aqueous extraction to determine the silage pH (using a digital pH meter (Sartorius PT-10; Sartorius AG, Göttingen, Germany), total volatile fatty acids (TVFA, measured by Markham's distillation apparatus), and lactic acid concentration (determination by spectrophotometer, Varincary 100, Australia, 610 nm), water-soluble carbohydrates (WSC, determination by spectrophotometer, Varincary 100, Australia, 625 nm) content, and buffering capacity (BC) (Kozloski *et al*. 2006). Briefly, 25 g of each silage sample was extracted with 225 mL of distilled water over 24 h, filtered using filter paper (Whatman no. 54), and the pH of the silage extract was recorded using a digital pH meter (Sartorius PT-10; Sartorius AG, Göttingen, Germany). The NH_3 concentration of the extract was determined by spectrophotometer (Varincary 100, Australia, 630 nm) according to phenol-hypochlorite method (Galyean, 1997) and WSC using the anthrone method (MAFF, 1986). Lactic acid and TVFA concentrations of the extract were quantified according to the methods described by Barnett and Reid (1957) and Figenschou and Marais (1991), respectively. The BC of the extracts expressed as the milliequivalents per liter of NaOH and HCl used was measured according to the method elucidated by Moharrery (2007). The Flieg Point (FP) of the silage samples was calculated using the equation presented by Moselhy *et al*. (2015) below:

$$FP= 220 + (2\times \% DM-15) - pH \times 40$$

Based on this index, the silages with scores of < 20, 21-40, 41-60, 61-80, and 81-100 were considered as very bad, bad, medium, good, and very good, respectively.

In vitro ruminal fermentation characteristics and gas production kinetics

The *in vitro* ruminal fermentation characteristics, including the gas, produced over 24 h of incubation (GP_{24}), pH, NH_3 concentration, and 24-h dry matter digestibility (DMD_{24})

were determined using the gas production technique described by Menke and Steingass (1988). The rumen fluid was obtained from three adults ruminally-fistulated Mehraban rams before morning feeding. The rams were fed *at libitum* twice daily (at 08:00 and 16:00 h) with a diet composed of alfalfa hay, SMCS, barley grain, corn grain, soybean meal, and mineral-vitamin premix, at ratios of 0.30, 0.30, 0.15, 0.15,0.09, and 0.01 on a DM basis and had free access to fresh water. The collected ruminal fluid was pooled and placed in pre-warmed (39 ˚C) insulated flask and was transported under anaerobic conditions to the laboratory. Pooled ruminal fluid was filtered through four layers of cheesecloth and then mixed continuously with CO_2 and maintained near 39 ˚C before usage. The rumen inoculum was prepared by mixing the rumen fluid with mineral buffer at a ratio of 1:2 (v/v). Samples of 200 mg of the dried silages were incubated in triplicate with 30 mL of the buffered rumen inoculum in 100 mL glass syringes (Fortuna, Häberle Labortechnik, Lonsee-Ettlenschieb, Germany). Three syringes without the fermentation substrate were incubated and considered as blanks. The syringes were incubated for 24 h in a water bath at 39 ˚C. At the end of incubation and after recording the GP_{24} volume, the syringe content was transferred to falcon tubes and immediately cooled using an ice water bowl to stop the fermentation and its pH was measured using a digital pH meter (Sartorius PT-10; Sartorius AG, Göttingen, Germany). The falcon tubes content was filtered using Dacron bags (3 cm×10 cm, 45 µm pore size), and aliquots of 4 ml of the supernatant were fixed with an equal volume of 0.2 N chloridric acid and kept at -20 ˚C for ammonia analysis. The filtrated residues were then oven-dried at 60 ˚C to a constant weight to calculate dry matter digestibility (DMD_{24}).

An additional set of incubation of 144 h was also conducted to evaluate the *in vitro* silages gas production kinetics. The incubation procedure was the same as that explained for the first incubations but with a longer incubation time. The gas produced at 2, 4, 6, 8, 12, 24, 48, 72, 96, 120, and 144 h of incubation was measured and data were fitted to the following model proposed by France *et al.* (1993) to estimate the ruminal fermentation kinetic parameters of the silages.

$$Y= A(1-e^{-[c(t-L)- b(\sqrt{t}-\sqrt{L})]})$$

Where:
Y: volume of gas production (GP) at time t (mL/200 mg DM).
A: asymptotic GP (mL/200 mg DM).
c: fractional rate of GP (h^{-1}).
b: GP constant coefficient ($h^{-1/2}$).
t: incubation time (h).
L: lag time (h^{-1}).

At the end of incubation, the syringe content was filtrated using Dacron bags (3×10 cm, 45 µm pore size) to estimate 144-h dry matter (DMD_{144}) and organic matter degradability (OMD_{144}) of the samples.

In vivo apparent digestibility of nutrients

Total tract digestibility of the silages was determined using 18 Mehraban *male lambs* with a body weight of 52.9 ± 6.2 kg. Before commencing the experiment, the lambs were threatened for internal parasites (Triclabendazole + Levamisole, 12 mL per lamb; Darou-Pakhsh Co., Iran), stratified by weight and randomly assigned to one of the experimental treatments (6 replicate). Lambs were housed in metabolic crates and received *ad libitum* only the experimental silages twice daily (at 08:00 and 16:00 h) and had free access to fresh water. After an adaptation period of 2 weeks to metabolic creates and experimental diets; the feeds offered, the refusals and feces samples were collected daily for each lamb over 7 days and kept frozen at -20 ˚C for subsequent analyses. The samples were then pooled to give a representative sample for each animal, dried at 55°C in a forced-air oven, and subsequently analyzed for DM, OM, CP, NDF, and ADF contents.

Statistical analysis

The *in vitro* experiments were repeated three times (run) on three different days. Data from these experiments were analyzed using the MIXED procedure of SAS (2004). The model included the fixed effect of treatment (different types of SMC) and the random effect of run (day). Data of SMC chemical composition, silage quality parameters, and those of *in vivo* assay were analyzed by the GLM procedure of SAS (SAS, 2004) using the following model.

$$Y_{ij}= \mu + T_i + e_{ij}$$

Where:
µ: overall mean.
T_i: effect of treatment i.
e_{ij}: random error.

The syringes and animals were considered as experimental units in *in vitro* and *in vivo* experiments, respectively. Statistical significance was declared at $P \leq 0.05$. The means for each estimated parameter and variable were compared among the treatments using Duncan's multiple range test.

RESULTS AND DISCUSSION

The results of the chemical analysis of silages are shown in Table 1.

Table 1 Chemical composition of the spent mushroom compost silages treated with different levels of molasses

Item	Treatments			SEM	P-value
	SMC_0	$SMC_{7.5}$	SMC_{15}		
DM (g/kg, fresh weight)	350[a]	350[a]	318[b]	4.60	0.0243
OM (g/kg, based on DM)	556[a]	528[b]	547[a]	3.19	0.0180
MM (g/kg, based on DM)	444[a]	472[b]	453[a]	3.19	0.0180
CP (g/kg, based on DM)	69.7	77.1	76.0	7.59	0.7739
NDF (g/kg, based on DM)	299[a]	278[b]	258[c]	2.92	0.0054
ADF (g/kg, based on DM)	215	212	202	4.62	0.2702

* Treatments included SMC_0: spent mushroom compost silage treated with 0% molasses (control); $SMC_{7.5}$: spent mushroom compost silage treated with 7.5% molasses and SMC_{15}: spent mushroom compost silage treated with 15% molasses.
DM: dry matter; OM: organic matter; MM: mineral matter; CP: crud protein; NDF: neutral detergent fiber and ADF: acid detergent fiber.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).

The DM and NDF contents decreased in SMC_{15} compared with the control, while OM content was less in the $SMC_{7.5}$ (P<0.05). The DM content of the silages was between 318 and 350 g/kg of fresh weight, which was close to the level reported by McDonald *et al.* (1991) for high-quality silage (350 g/kg of fresh wt). However, the appropriate range of silage DM depends on the characteristics of the silage material including the concentrations of WSC, CP, minerals, and physical texture of the forage (Romney *et al.* 2000). The low OM content of the silages was due to the contamination of spent mushroom compost with soil (Bakshi and Langar, 1991; Valmaseda *et al.* 1991; Fazaeli *et al.* 2014). The changes in the NDF contents in SMCS could be due to different extent of fermentation and utilization of WSC and cell wall components during ensiling, and leakage of the silage's effluent accompanied with soluble nutrients in molasses-treated silages (McDonald *et al.* 1991). It appears that including molasses in SMC has intensified fermentation through enhancing WSC content that by a consequence resulted in a decreased NDF content in $SMC_{7.5}$ and SMC_{15} (Mahala and Khalifa, 2007; Balakhial *et al.* 2008; Rezaei *et al.* 2009). These results were in line with previous research that reported a higher cell wall degradability in the silages treated with molasses (Baytok *et al.* 2005; Arbabi and Ghoorchi, 2010). However, a higher inclusion level of molasses might have caused a higher OM content in SMC_{15} compared with $SMC_{7.5}$. Moreover, in this study, the CP content of $SMC_{7.5}$ and SMC_{15} was higher than 70 g/kg DM, providing minimum N for optimal growth of rumen microorganisms, promoting fiber degradation (Lazzarini *et al.* 2009; Sampaio *et al.* 2010). However, it is worth noting that the CP content of these silages is insufficient to support maximum growth of the rumen microorganism, especially when incorporated in a large quantity in the ration, hence, enrichment of these silages with Nitrogen sources like urea could improve their nutritional value. On the other hand, a higher WSC content generally promotes a rapid decrease in pH, preventing protein degradation and nitrogen loss in silages (McDonald *et al.* 1991).

This could explain partially an equal CP content in $SMC_{7.5}$ and SMC_{15} compared with the control, though molasses could also enrich the silages with N, compensating part of N lost during ensiling of $SMC_{7.5}$ and SMC_{15}.

The result of fermentation characteristics of silage is shown in Table 2. The TVFA, lactic acid, WSC content, and FP increased, but the pH and BC decreased with increasing inclusion level of molasses in the silages (P<0.05). The NH_3 concentration did not change with the molasses treatment of the silages. The pH is one of the important indexes of the silage fermentation quality (Yang *et al.* 2004).

The pH value of high-quality silage has been reported within the range of 3.7 to 4.2 (McDonald *et al.* 2011). A relatively high value for the pH of the silage in this study might be related to inadequate WSC content in the pre-ensiled fresh material (despite adding molasses), which has limited the fermentation extent. As expected, the pH value of the $SMC_{7.5}$ and SMC_{15} was lower than that SMC_0 due to the fermentation of WSC to organic acids. These results are consistent with those of Moselhy *et al.* (2015) and Abbasi *et al.* (2018) who reported a decline in the silage pH with their treatment with molasses. Molasses is a carbohydrate source with a high WSC (700 g/kg of DM; McDonald *et al.* 2011) that increases the fermentation end product such as TVFA and lactic acid of silages by supplying rapidly fermentable energy to lactic acid bacteria during ensiling (Baytok *et al.* 2005).

It has well been documented that including molasses in silages generally improves their fermentation characteristics mainly by stimulating the growth of lactic acid bacteria and subsequently by the rapid production of lactic acid in silage (Chen *et al.* 2017; Abbasi *et al.* 2018), restriction other undesirable microorganisms such as clostridia and enterobacteria (Yang *et al.* 2004).

In the present study, the silages treated with molasses provided greater WSC for lactic acid bacteria in comparison to the control silage, resulting in an increased concentration of residual WSC in the silages.

Table 2 Effect of different levels of molasses on fermentation characteristics of the spent mushroom compost silages

Item	Treatments*			SEM	P-value
	SMC_0	$SMC_{7.5}$	SMC_{15}		
pH	6.48[a]	6.01[b]	5.75[c]	0.004	< 0.0001
TVFA (mmol/L)	18.0[c]	22.5[b]	48.4[a]	0.95	< 0.0001
Lactic acid (g/kg of DM)	4.63[c]	11.3[b]	13.8[a]	0.39	0.0010
WSC (g/kg of DM)	16.4[b]	19.6[ab]	25.2[a]	0.16	0.0431
NH_3 (mmol/L)	6.86	4.11	4.25	0.719	0.1203
BC (meq/L)	31.71[a]	27.53[b]	23.36[c]	1.223	0.0189
Flieg Point	15.8[b]	34.9[a]	38.8[a]	0.93	< 0.0001

* Treatments included SMC_0: spent mushroom compost silage treated with 0% molasses (control); $SMC_{7.5}$: spent mushroom compost silage treated with 7.5% molasses and SMC_{15}: spent mushroom compost silage treated with 15% molasses.
TVFA: total volatile fatty acids; WSC: water soluble carbohydrates and BC: buffering capacity.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).

In the current study, the NH_3 concentration decreased numerically in $SMC_{7.5}$ and SMC_{15}, indicating that a rapid decrease in pH might have restricted protein degradation and deamination activity (McDonald *et al*. 1991; Xia *et al.* 2018). The BC is another important factor affecting the quality of the silage (Jian *et al*. 2017). A higher BC of silages is generally considered negative. This index is highly correlated with organic acids concentration (especially lactic acid), cationic minerals and CP content in the silage (Playne and McDonald, 1966). Compared with grasses, ensiling legumes and feedstuffs with a low WSC and high BC are more difficult because of an inadequate decrease of these silage pH (Kristensen, 1992). Different strategies, including the addition of citrus or beet pulp, organic acids, microbial additives, and molasses can reduce BC and improve the fermentation quality of these types of feedstuffs (Bolsen *et al.* 1996; Shao *et al.* 2005; Abbasi *et al.* 2018). Consistent with the findings of Jian *et al.* (2017), the silages treated with molasses in the current study enhanced their FP value. However, the FP value of all the silages was low, indicating a relatively poor quality of the silages.

The result of *in vitro* ruminal fermentation characteristics after incubation for 24-h is shown in Table 3. The GP_{24} and DMD_{24} increased with increasing levels of molasses in the silages (P<0.05). However, molasses treatment did not affect the pH and NH_3 concentration of the silages. The ruminal NH_3 concentrations of all silages were within the range recommended (McDonald *et al.* 2011). The SMC_{15} had greater GP_{24} and DMD_{24} compared with the other silages, which could most probably be due to its higher residual WSC and a lower NDF content compared with the other silages (Van Soest, 1994; Chamberlain and Wilkinson, 2000; Moselhy *et al.* 2015). In a study conducted on whole-crop wheat silage, Xia *et al*. (2018) reported that there is negatively a correlation between NDF content and maximum gas production. Another reason of raised digestibility was less ash content which can improve organic matter (degradable substrate) contents over the fermentation process, leading to increase *in vitro* gas production and digestibility. Previous studies have indicated that supplementing many types of silage, including potato hash (Nkosi and Meeske, 2010), Bermuda grass (Nayigihugu *et al.* 1995), and whole corn plant (Aksu *et al.* 2006) with molasses have improved gas production and digestibility. Nkosi and Meeske (2010) stated that adding molasses to potato hash at ensiling improved digestibility due to high fermentable sugars in molasses which led to the growth of lactic acid bacteria and promote the ensiling process. Such results were observed by Li *et al*. (2014) on fermentation quality and *in vitro* gas production of king grass silage when adding molasses. Indeed, fermentable energy is generally considered the limiting factor for ruminal bacterial activity, thus supplementing a fermentable energy source could improve rumen fermentation (McDonald *et al.* 1991).

The results of *in vitro* gas production kinetics of the silages are shown in Table 4. The molasses-treated silages ($SMC_{7.5}$ and SMC_{15}) had a higher GP_{144}, A, b, DMD_{144}, and OMD_{144}, and lower L and c values compared with the SMC_0 (P<0.05). Improved A value in the $SMC_{7.5}$ and SMC_{15} was consistent with the results of Rezaei *et al.* (2009). But Mahala and Khalifa (2007) reported that A and c values were not affected in silage treated with molasses. Neghabi *et al*. (2013) also reported more A value and digestible organic matter (DOM) over 96 h of incubation. Many studies have reported an improvement in GP and digestibility following the addition of molasses to silage (Aksu *et al*. 2006; Hashemzadeh-Cigari *et al*. 2011; Babaeinasab *et al.* 2015), but Xia *et al*. (2018) reported that treatment of whole crop wheat silage with 2, 4 and 6% molasses did not affect DMD, GP, A, L, and c parameters. This may be due to the low amount of molasses used. Since most of the gas produced during incubation originates from feed carbohydrates, enrichment of the silages with a carbohydrate source such as molasses increases microbial colonization and activity in the rumen and reduces lag time (Neghabi *et al.* 2013).

The results of *in vivo* apparent digestibility of the silages are shown in Table 5.

Table 3 Effect of different levels of molasses on *in vitro* ruminal fermentation characteristics of the spent mushroom compost silages

Item	Treatments*			SEM	P-value
	SMC_0	$SMC_{7.5}$	SMC_{15}		
pH	7.05	7.05	7.07	0.018	0.6716
GP_{24}	16.4^{c}	27.5^{b}	32.5^{a}	0.395	< 0.0001
NH_3 (mmol/L)	9.03	9.04	8.57	0.429	0.6846
DMD_{24}	38.8^{c}	42.2^{b}	46.1^{a}	0.701	< 0.0001

* Treatments included SMC_0: spent mushroom compost silage treated with 0% molasses (control); $SMC_{7.5}$: spent mushroom compost silage treated with 7.5% molasses and SMC_{15}: spent mushroom compost silage treated with 15% molasses.
GP_{24}: volume of gas produced over 24 h of incubation (mL/200 mg DM) and DMD_{24}: dry matter digestibility after incubation for 24h (%).
The means within the same row with at least one common letter, do not have significant difference (P>0.05).

Table 4 Effect of different levels of molasses on *in vitro* gas production kinetics of the spent mushroom compost silages

Item	Treatments*			SEM	P-value
	SMC_0	$SMC_{7.5}$	SMC_{15}		
GP_{144}	25.6^{b}	32.3^{a}	35.6^{a}	1.67	0.0010
A	26.0^{b}	33.3^{a}	36.1^{a}	1.50	< 0.0001
L	2.28^{a}	1.43^{ab}	0.36^{b}	0.46	0.0238
b	-0.042^{b}	-0.008^{a}	-0.009^{a}	0.007	0.0026
c	0.034^{a}	0.026^{b}	0.028^{b}	0.001	0.0030
DMD_{144}	73.4^{c}	77.3^{b}	84.5^{a}	1.14	< 0.0001
OMD_{144}	82.7^{b}	85.9^{b}	90.5^{a}	1.363	0.0014

* Treatments included SMC_0: spent mushroom compost silage treated with 0% molasses (control); $SMC_{7.5}$: spent mushroom compost silage treated with 7.5% molasses and SMC_{15}: spent mushroom compost silage treated with 15% molasses.
GP_{144}: volume of gas produced after 144 h of incubation (mL/200 mg DM); A: asymptotic gas production (mL/200 mg DM); L: lag time (h^{-1}); b: gas production constant coefficient ($h^{-1/2}$); c: fractional rate of gas production (h^{-1}); DMD_{144}: dry matter digestibility after 144 h of incubation (%) and OMD_{144}: organic matter digestibility after 144 h of incubation (%).
The means within the same row with at least one common letter, do not have significant difference (P>0.05).

Table 5 Effect of different levels of molasses on *in vivo* apparent digestibility (%) of the spent mushroom compost silages

Item	Treatments*			SEM	P-value		
	SMC_0	$SMC_{7.5}$	SMC_{15}		Linear	Quadratic	Treatment
DM	33.7^{b}	38.7^{ab}	41.5^{a}	2.04	0.017	0.058	0.0479
OM	38.7^{b}	43.4^{ab}	46.3^{a}	1.71	0.007	0.028	0.0280
CP	27.2^{b}	33.1^{a}	37.1^{a}	1.64	0.001	0.004	0.0042
NDF	25.3	26.2	31.5	2.06	0.056	0.121	0.1209
ADF	20.2^{b}	21.8^{ab}	25.1^{a}	1.19	0.011	0.039	0.0385

* Treatments included SMC_0: spent mushroom compost silage treated with 0% molasses (control); $SMC_{7.5}$: spent mushroom compost silage treated with 7.5% molasses and SMC_{15}: spent mushroom compost silage treated with 15% molasses.
DM: dry matter; OM: organic matter; MM: mineral matter; CP: crud protein; NDF: neutral detergent fiber and ADF: acid detergent fiber.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).

Lambs fed the SMC_{15} diet had higher (P<0.05) DM, OM, CP, and ADF digestibility compared to those in the SMC_0. Treatment with molasses improved the nutrient digestibility (except for NDF) in a linear and quadratic manner (P<0.05). The NDF digestibility also tended to increase linearly (P=0.056) with molasses treatment. Nitrogen deficiency may be one of the causes of insignificant treatment effect on this parameter. Thus, it is probable that the inclusion of nitrogen sources improves NDF digestibility by synchronizing the availability of energy and Nitrogen. Improved nutrients digestibility of SMC_{15} might be related to a high WSC content in this silage, which acts as a rapid fermentable energy source for the growth of rumen microbes, resulting in improved growth performance of lambs compared with the control (McDonald *et al.* 2011). A high WSC is possible that has provided a synchronized supply of energy and CP sources for microbial N synthesis in the rumen (Seo *et al.* 2010; Azizi-Shotorkhoft *et al.* 2013).

In addition, an increased coefficient of nutrient digestibility could be related to a less NDF content of the silages treated with molasses (particularly 15% molasses). In a study conducted by Baytok *et al.* (2005), molasses-treated silage had a greater NDF digestibility than the control. The results on the nutrients digestibility obtained in the current study were consistent with those of Broderick and Radloff (2004), who observed a linear increase in digestibility coefficients of DM, OM, and ADF with increasing levels of molasses (0, 40, 80 or 120 g/kg of DM diet) that replaced corn grain in the diet of dairy cattle. Moreover, Azizi-Shotorkhoft *et al.* (2012) also reported that the apparent digestibility of DM, CP and NDF increased by replacing conventional carbohydrate sources like barley and corn with molasses (240 g/kg DM diet).

These results suggest that the treatment of mushroom compost silage with molasses could improve its nutritional value as a new by-product feedstuff that can be used par-

tially in the diet of ruminants in arid and semi-arid regions with feed-shortage challenge.

CONCLUSION

Based on the results from this study, it can be concluded the spent mushroom (*Agaricus bisporus*) compost silage has the potential to be considered as a by-product feed for ruminants. The chemical composition and fermentation characteristics of SMC were indicative of its poor quality. However, treatment with molasses improved its fermentation characteristics, ruminal digestibility, and fermentation. Thus, molasses-treated SMC can be considered a cost-effective by-product of mushroom production farms that can be used partially in the diet of ruminants.

ACKNOWLEDGEMENT

This research was supported by the faculty of agriculture, Bu-Ali Sina University. The authors would like to thank also Sina Mushroom Farm, for providing the spent mushroom compost.

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