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Use of sugarcane molasses as an additive can improve the silage quality of sorghum-sudangrass hybrid

Hafiz Naveed Ramzan[1, 3,*], Asif Tanveer[1], Rizwan Maqbool[1], Hafiz Muhammad Akram[3] and Muhammad Aslam Mirza[2]

[1]Department of Agronomy, University of Agriculture Faisalabad, 38000, Pakistan;[2]Institute of Animal and Dairy Sciences, University of Agriculture Faisalabad, 38000, Pakistan; [3]Agronomic Research Institute, Ayub Agricultural Research Institute, Faisalabad, 38000, Pakistan
[*]Corresponding author's e-mail: naveedramzan_uaf@hotmail.com

This study was aimed to evaluate the effect of sugarcane molasses on the silage quality of sorghum-sudangrass hybrid (*Sorghum bicolor* × *Sorghum sudanense*). To explore this objective Sorghum-sudangrass hybrid was harvested at the milking stage and well-chopped for making silage in the laboratory silos by using sugarcane molasses at the rate of 0, 1, 2, and 3%. Silage developed so, was analyzed for nutritive quality traits (dry matter, pH, crude protein, neutral detergent fiber, acid detergent fiber, cellulose, hemicelluloses and ash). Silage quality was also assessed by calculating digestible dry matter, dry matter intake, digestible energy, metabolizable energy and relative feed value. Flieg score was deliberated by using the pH and dry matter. The results of the research revealed that application of molasses improved dry matter (26.27%), crude protein (8.14) and ash contents (7.68) as compared to the control, but had lower values of pH (3.99), neutral detergent fiber (57.86), acid detergent fiber (30.74), lignin (3.72), cellulose (27.02) and hemicelluloses (27.13) in comparison with the untreated silage (control). Flieg score of treated silage was also in the category of very good. All these findings lead us to conclude that the silage quality of sorghum-sudangrass can be considerably improved by the use of sugarcane molasses as an additive. Molasses addition at a rate of 3% can improve the nutritive value of sorghum-sudangrass silage to the maximum extent.
Keywords: Silage, molasses, sorghum-sudangrass, additive, nutritive quality, sugar industry.

INTRODUCTION

Population growth and urbanization are placing pressure on the worldwide demand for animal products and boosting livestock production is the key problem (Hume *et al*., 2011; Chen *et al*., 2020), but climate change is putting pressure on total agricultural productivity (Getachew *et al*., 2016). Developing countries such as Pakistan are no exception, and the livestock sector in Pakistan has recently been prioritized for the sake of food security and economic growth (Govt. of Pakistan, 2020). The primary impediment to the growth of Pakistan's livestock sector is a lack of nutritional availability (Iqbal *et al*., 2015). Poor fodder yields (Afzal *et al*., 2013), continuously decreasing area under fodder crops in conjunction with fodder scarcity periods (Hussain *et al*., 2012) and conventional livestock feeding habits (Sarwar *et al*., 2002) are a few more factors for lower animal productivity.

The livestock sector can only flourish if there is a solid fodder basis (Nasiyev, 2013) and a consistent supply of high-quality fodder in sufficient quantities is the key to reaching this milestone (Hussain *et al*., 2012). The cheapest source of the animal feeding system in Pakistan is fodder, which is expected to offer more than 80% of nutrients (Iqbal *et al*., 2015), yet our fodder production system can only provide 50% of the requirements for livestock (Amanullah *et al*., 2007). This gap is expected to expand, which must be addressed by investigating both traditional and modern methods of feeding animals (Habib *et al*., 2016). The introduction of higher-yielding fodder varieties (Bilal, 2009), the inclusion of multicut fodders in our fodder production systems and the adoption of preservation methods, particularly during times of abundant fodder growth (Iqbal and Bethune, 2015) are among the leading avenues for addressing the asymmetrical supply of good quality fodder for livestock.

Because of its multicut nature (Bibi *et al*., 2012), extremely leafy and fast-growing habit (Berenji and Dahlberg, 2004), greater leaf to stem ratio (Uzun *et al*., 2009), good regrowth ability (Kim *et al*., 2021) and higher yields (Agarwal and

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Shrotria, 2005; Liang *et al*., 2018), Sorghum-sudangrass hybrid (SSG) is preferred as part of the solution. In comparison to maize, SSG can generate dry matter in comparable quantities for silage (Contreras-Govea *et al*., 2009), has equivalent yield potential (Getachew *et al*., 2016) and has greater water use efficiency and drought resistance (Uzun and Cigdem, 2005). It is not new to Pakistani farmers because it has been present in farmer fields for over a half-century, but it has recently regained popularity due to its high tonnage, multicut nature, and ability to provide green foliage during shortage periods (Hussain *et al*., 2012).

During times of plentiful growth, fodders can be stored as silage or hay (Tauqir *et al*., 2009). Presently, silage is the most preserved ruminant feed source. Silage, when formed properly, provides the same or even higher value as ensiled fodder (Iqbal and Bethune, 2015). Because of its relished consumption, good quality silage can increase animal health and production (Varadyova *et al*., 2010). A range of additives, including chemicals, bacterial inoculants and enzymes, have been explored to improve silage quality, either by boosting nutritional content or by addressing various management difficulties throughout the ensiling process (Tyrolova *et al*., 2017; Muck *et al*., 2018).

Molasses is a universal additive that has been used for a long time to improve fermentation and silage quality (Kaiser *et al*., 2004). Because molasses enriches the treated fodder with carbohydrates, the possibilities of silage spoiling are reduced due to a reduction in oxygen ingress as well as an increase in crude protein content (Bilal, 2009; Hartinger *et al*., 2019). Since the last ten years, Pakistan has produced more than 2 million tons of readily available sugarcane molasses (Pakistan Sugar Mills Association, 2020).

If molasses is added, SSG is a suitable crop for silage (Iqbal and Bethune, 2015; Basaran *et al*., 2017). Molasses treatment of forage sorghum improves silage quality in terms of physical, chemical and fermentation performance (Mahala and Khalifa, 2007). Despite the critical need of the livestock sector, not much research has been conducted in Pakistan to assess the impact of molasses as an additive for SSG silage, however some researchers have investigated the idea of utilizing molasses in the silage of other crops.

Keeping foregoing in mind, the current study was designed to explore the impact of molasses on the silage quality of sorghum-sudangrass hybrid.

MATERIALS AND METHODS

***Experimental design and treatment detail*:** The study was conducted during 2019-2020 at the University of Agriculture, Faisalabad (altitude 184.4 m, latitude 31.40º N, longitude 73.05º E). The treatments comprised of four levels of molasses as 0% (M_1), 1% (M_2), 2% (M_3) and 3% (M_4) on w/w basis. Sorghum-sudangrass hybrid (SX-17) was harvested at the milking stage (75 days after sowing) and chopped into 2-3 cm pieces. The chopped material was treated with respective molasses levels and filled so tightly that there was no chance of air entry in each plastic jar (one kg capacity). The jar was then sealed with a wrapping tap to prevent air entry. The laboratory silos (jars) were kept at ambient temperature (25-30 °C) in the laboratory. Completely randomized design (CRD) was used with four replications. The silos were opened 45 days after ensiling and the evaluation was carried out on the basis of various attributes (dry matter contents, pH of silage, crude protein, neutral detergent fiber, acid detergent fiber, lignin, cellulose, hemicelluloses and total ash).

***Procedure for recording data*:** Silage pH was measured after 45 days of ensiling immediately after opening the laboratory silos. A glass electrode pH meter was used for pH determination. The dry matter (DM) content was determined by drying the samples at 65°C for 48 h to a stable weight and then the samples were ground for further analysis. Chemical analysis was done for crude protein (CP) and ash (A.O.A.C, 1990) and for fiber fractions like acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose and lignin (Van Soest *et al*., 1991). Hemicellulose was calculated by subtracting the ADF from the values of NDF.

Flieg score, as reported by Kilic (1986), was calculated using following formula:

$$Flieg\ Score = 220 + (2 \times Dry\ Matter\ \% - 15) - 40 \times pH \quad (1)$$

The Flieg score with value 81-100, 61-80, 41-60, 21-40 and 0-20 represents the silage quality as very good, good, medium, low and poor, respectively.

Relative feed value (RFV) as formulated by Rohweder *et al*. (1978) was calculated as below:

$$RFV = DDM\% \times DMI\% \times 0.775 \quad (2)$$

Where, DDM is digestible dry matter as % of dry matter and DMI is dry matter intake and were calculated by the following formulae:

$$DDM = 88.9 - (0.779 \times ADF\%) \quad (3)$$

$$DMI = (120/\ NDF\%) \quad (4)$$

Digestible energy (DE) and metabolizable energy (ME) were calculated as were reported by Arbabi and Ghoorchi (2008) by using following formulae:

$$DE = 0.027 + 0.0427(DDM\%) \quad (5)$$

$$ME = DE \times 0.821 \quad (6)$$

***Statistical Analysis*:** The data of experiment were subjected to analysis by using statistical package Statistix 8.1 (Analytical Software, USA). Tukey's Honest Significant Difference (HSD) test at 5% probability level was used for comparing the difference among treatments' means (Steel *et al.*, 1997).

RESULTS

Molasses significantly influenced the chemical properties of SSG silage, including dry matter content, pH, crude protein, neutral detergent fiber, acid detergent fiber, lignin, cellulose, hemicelluloses, and total ash (Fig. 1-4; Table 1).

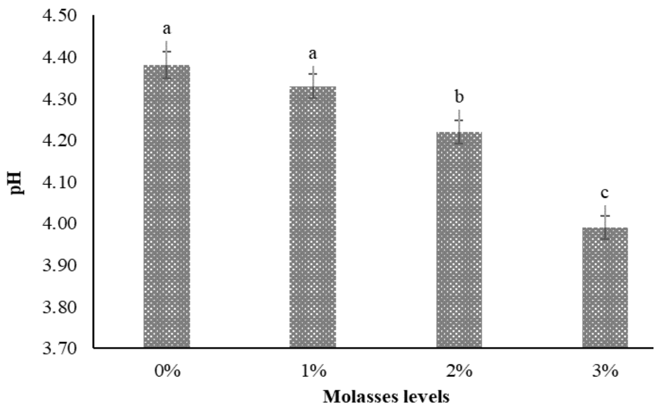

Figure 1. Impact of various levels of sugarcane molasses on pH of SSG silage. HSD @ 5% = 0.098 (Values sharing similar letters do not vary at $p \geq 5\%$). Molasses levels 0, 1, 2 and 3%.

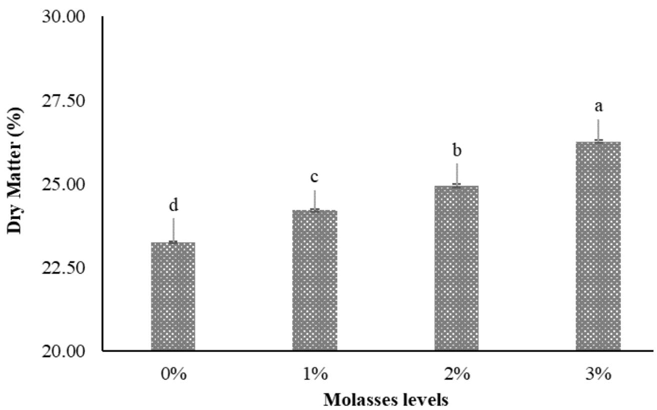

Figure 2. Impact of various levels of sugarcane molasses on dry matter of SSG silage. HSD @ 5% = 0.205 (Values sharing similar letters do not vary at $p \geq 5\%$). Molasses levels 0, 1, 2 and 3%.

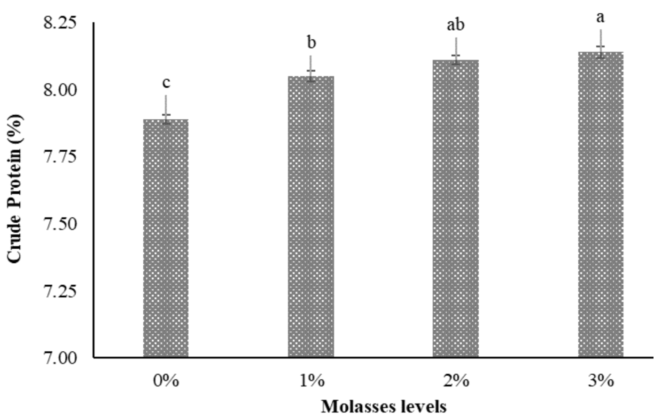

Figure 3. Impact of various levels of sugarcane molasses on crude protein of SSG silage. HSD @ 5% = 0.086 (Values sharing similar letters do not vary at $p \geq 5\%$). Molasses levels 0, 1, 2 and 3%.

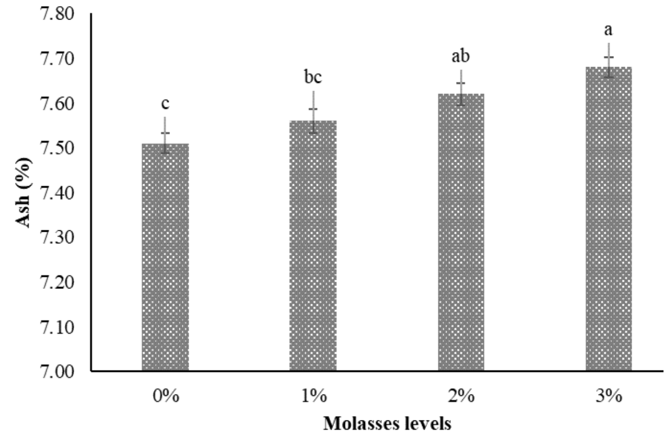

Figure 4. Impact of various levels of sugarcane molasses on ash contents of SSG silage. HSD @ 5% = 0.105 (Values sharing similar letters do not vary at $p \geq 5\%$). Molasses levels 0, 1, 2 and 3%.

Silage pH is critical when determining the quality of any silage. Figure 1 shows that when silage was treated with molasses, this key factor was significantly impacted. Figure 1 shows that using molasses at 3% resulted in the lowest pH (3.99), followed by using molasses at 2%. Under control, however, the maximum pH (4.38) was discovered. When molasses at 3% was applied to silage, the pH decreased by 9% when compared to the control.

When molasses was added, the dry matter, crude protein, and ash contents improved as compared to the control. Figures 2-4 show that using sugarcane molasses at 3% resulted in higher dry matter contents (26.27%), crude protein (8.14%), and ash contents (7.86%) than using a lower dose of molasses at 2%. The control treatment yielded the lowest dry matter content (23.25%), crude protein (7.89%), and ash content (7.51%). As molasses at 3% was applied to silage, the dry matter, crude protein, and ash contents increased by 13.0, 3.0, and 3.0 percent, respectively, when compared to the control.

Fiber analysis is critical for determining the diet value of silage. Table 1 shows that the application of molasses had a significant effect on NDF, ADF, lignin, cellulose, and hemicellulose. The lowest NDF (57.86), ADF (30.74), lignin (3.72), cellulose (27.02), and hemicellulose (27.13) across varied molasses application rates were observed by using molasses @ 3 percent, followed by those using molasses @ 2 percent. Under control, however, maximum values for NDF (61.33), ADF (33.62), lignin (4.22), cellulose (29.40), and hemicellulose (27.72) were obtained. The application of molasses at 3% resulted in a decrease of 6, 9, 12, 8 and 2% in NDF, ADF, lignin, cellulose, and hemicellulose, respectively, when compared to the control.

As shown in Table 2, the addition of cane molasses improved the silage quality indicators DDM, DMI, DE, ME, RFV and Flieg score. Maximum values for DDM (65.23), DMI (2.07), DE (2.81), ME (2.31), RFV (105) and Flieg Score (98) were

Table 1. Impact of various levels of sugarcane molasses on neutral detergent fiber, acid detergent fiber, lignin, cellulose and hemicellulose of sorghum-sudangrass hybrid silage

Molasses levels	Neutral detergent fiber (%)	Acid detergent fiber (%)	Lignin (%)	Cellulose (%)	Hemicellulose (%)
0% (control)	61.33±0.100a	33.62±0.048a	4.22±0.068a	29.40±0.043a	27.72±0.101a
1%	59.38±0.080b	31.90±0.058b	4.05±0.078a	27.85±0.045b	27.49±0.100ab
2%	58.45±0.063c	31.14±0.052c	3.97±0.062ab	27.17±0.038c	27.32±0.084b
3%	57.86±0.091d	30.74±0.056d	3.72±0.058b	27.02±0.031d	27.13±0.093b
HSD value	0.335	0.235	0.265	0.127	0.388

Means values within a column sharing a letter in common do not differ at $p = 0.05$ according to HSD test

Table 2. Impact of various levels of sugarcane molasses on digestible dry matter, dry matter intake, digestible energy, metabolizable energy, relative feed value and flieg score of sorghum-sudangrass hybrid silage

Molasses levels	Digestible dry matter (%)	Dry matter intake (%)	Digestible energy Mcal/kg)	Metabolizable energy (Mcal/kg)	Relative feed value	Flieg score
0% (control)	63.02±0.062d	1.96±0.0042d	2.72±0.0043d	2.23±0.0088d	96±0.326d	76±1.339d
1%	64.34±0.050c	2.02±0.0034c	2.78±0.0041c	2.28±0.0085c	101±0.308c	80±1.130c
2%	64.93±0.066b	2.05±0.0041b	2.80±0.0048b	2.29±0.0090b	103±0.418b	86±1.006b
3%	65.23±0.047a	2.07±0.0036a	2.81±0.0054a	2.31±0.0078a	105±0.370a	98±1.144a
HSD value	0.179	0.013	0.010	0.010	0.96	3.39

Means values within a column sharing a letter in common do not differ at $p = 0.05$ according to HSD test

obtained by applying molasses at 3%, followed by molasses at 2%; however, minimum values for DDM (63.02), DMI (1.96), DE (2.72), ME (2.23), RFV (96), and Flieg Score (76) were obtained under control.

DISCUSSION

pH, which evaluates silage fermentation, is the most important indicator of silage quality (Kaiser *et al*., 2004). Deniz *et al*. (2001) discovered a positive relationship between pH reduction and silage quality. Achieving a low pH is desirable for high-quality silage (Yang *et al*., 2004). In the current investigation, the lowest pH value (3.99) was found at the maximum level of molasses (3%). This decrease in pH could be due to the increased activity of lactic acid bacteria in producing lactic acid, which would frighten the clostridia. This is due to more easily available carbohydrates acting as a medium for lactic acid bacteria. Our findings are consistent with previously published research (Bilal, 2009; Kaya *et al*., 2009; Latif *et al*., 2015). However, several researchers have reported opposite results to our study regarding the effect of molasses on silage pH (Keskin *et al*., 2005; Naeini *et al*., 2014), whereas Baytok *et al*. (2005) and Fallah (2019) stated that pH was not significantly affected.

When compared to the control, the DM content of the silage was greater due to the use of molasses as an additive. More DM recovery with molasses could be attributed to the inclusion of water soluble carbohydrates, which increases fermentation characteristics. Once the silage is stable, there is no more fermentation, and at a very low pH, bacteria become a part of the medium, making DM reduction impossible (Lyimo *et al*., 2016). According to researches, adding molasses to silages boosted dry matter content (Nursoy *et al*., 2003), because molasses contains more dry matter than silage material. Baytok *et al*. (2005), Keskin *et al*. (2005), Arbabi and Ghoorchi (2008), and Bilal (2009) all observed improvements in dry matter contents of molasses-treated silage compared to untreated silage. Touqir *et al*. (2007) and Kang *et al*. (2018) found no influence of molasses on silage DM, which contradicts our findings.

The dietary protein content is critical for optimal dietary management (Kaiser *et al*., 2004). In our investigation, CP increased with increasing molasses content, and the maximum value for this essential parameter was obtained in the silage treated with molasses at 3%. This increase may have been produced by molasses with relatively higher CP contents (Baytok *et al*., 2005), and suppression of proteolytic activity has been proposed as another reason for the enhanced CP of the molasses-treated silage (Kung *et al*., 2000). Efficient fermentation and preservation of additive-treated silage do not provide an open field for the activity of various types of bacteria, so these become a part of the silage and CP contents are improved because the bacteria are protein in nature (Yang *et al*., 2004). There is conflicting evidence in the literature about the impact of molasses on the CP content of the silage. Molasses addition to silage increased (Lyimo *et al*., 2016; Fallah, 2019), did not impact (Kang *et al*., 2018), or even decreased (Moore and Kennedy, 1994) CP contents.

The addition of molasses greatly improved ash contents and each level of additive significantly improved ash contents. Several prior research (Mustafa *et al*., 2000; Bilal, 2009) corroborated similar findings and indicated that when molasses was added during ensiling, ash content increased to some level. This rise could be ascribed to lower DM losses in the treated silage during ensiling, whereas the decrease in control could be due to DM loss. According to Mahala and Khalifa (2007) and Lyimo *et al*. (2016), the increase in molasses level induced an increase in ash value due to the high mineral content in molasses.

Fiber fraction concentrations (NDF, ADF, lignin, cellulose, and hemicellulose) were significantly lower in molasses-treated silage than in untreated silage. This decrease in fiber fractions could be attributed to two factors: first, increased cell wall digestion mediated by increased lactic acid bacterial activity and hence superior silage fermentation due to molasses addition (Baytok *et al*., 2005), and second, reduced ADF concentrations of the additives (Bingol and Baytok, 2003). Many researchers have reported findings that are similar to ours (Baytok *et al*., 2005; Keskin *et al*., 2005; Arbabi and Ghoorchi, 2008; Naeini *et al*., 2014; Fallah, 2019).

Carbohydrate-containing additives give the essential energy for lactic acid bacteria, and their activity is increased, resulting in a pH drop and an improvement in the ultimate quality of the treated silage. Because DDM, DE and ME are all dependent on ADF contents, any drop in ADF content results in an increase in DDM. In this investigation, molasses levels of 3% resulted in the lowest ADF contents, resulting in the maximum dry matter digestion, DE, and ME. Dry matter intake, which is derived from silage NDF values, is another key factor in determining silage quality. NDF at its most decreased level was obtained at the highest level of all the tested molasses levels, resulting in the highest intake value of the dry matter. A similar trend was found in the case of RFV, which was improved with each increment in the molasses level, indicating that the best quality was obtained at the highest tested amount of molasses (3%). Flieg score also indicates that, of the four tested amounts of molasses, silage of the highest quality was obtained by applying molasses at 3%, whereas untreated silage (control) was of the lowest quality. This improvement with each increased molasses content is the result of a drop in pH and an increase in the DM of the treated silage. Our findings are consistent with those of Baytok *et al*. (2005) and Arbabi and Ghoorchi (2008).

***Conclusion*:** Pakistan has a well-established sugar industry with ample molasses production, some of which could be used for SSG silage. The study's findings demonstrated that molasses addition enhanced dry matter, crude protein and ash contents but resulted in lower pH and fiber fraction values when compared to untreated silage (control). Based on these findings, it is concluded that sorghum-sudangrass hybrid can be ensiled for promising silage quality employing molasses at a rate of 3% as a silage additive. Further research on the effect of cane molasses-treated sorghum-sudangrass hybrid silage on animal growth performance is recommended.

***Authors contributions*:** The authors declare that they have contributed to the article equally.

***Conflict of interest*:** The authors declare that there is no conflict of interest.

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