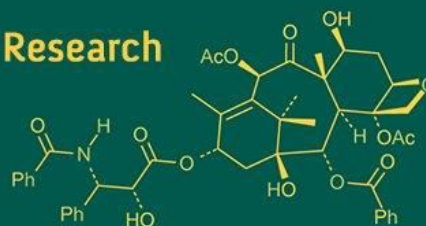


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Effect of adding different levels of liquid whey and molasses on quality and nutritive value of wild reed plant silage

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Abstract

This study was carried out in the laboratory to investigate the effect of adding different levels of liquid whey (LW) as a natural source of lactic acid bacteria (LAB, 3.5×10^6 cfu/ml) and molasses (M) on quality and nutritive value of wild reed silage (RS). Reed plants were chopped into 1.5-2 cm of length. Liquid whey was added to ensure introducing LAB at zero, low and high levels (0, 1×10^5 and 1×10^6 cfu/g FM). Molasses was added at levels of 4, 6 and 8%. Additives were mixed with quantity of water to ensure that the final DM content of RS at ensiling was about 35%. Samples of RS were stored in double plastic bags for 60 days. The color of RS samples ranged from dark green and greenish yellow. Diluted to concentrated fruit vinegar odor was emitted from RS samples prepared with LW. All RS samples had good texture with some mold found in those prepared without LW. Adding LW at low and high levels resulted in lower ($P < 0.01$) DM loss (7.97 and 5.10%), aerobic stability (AS, 143.33 and 145.26 hrs.) and buffering capacity (BC) together with higher ($P < 0.01$) Fleig points (Fp, 75.21 and 86.70), and both *in vitro* dry and organic digestibilities (IVDMD, IVOMD). With exception of AS which was increased ($P < 0.05$) from 144.06 to 150.26 and 151 hrs, similar results were obtained due to adding increased M levels. Results of this study showed that all characteristics of quality and nutritive value of RS were significantly affected by interaction between levels of liquid whey and molasses. In conclusion, wild reed plant can be effectively ensiled with addition of both by-product, liquid whey and molasses.

Keywords: Liquid whey, molasses, wild reed, silage, quality and nutritive value

Introduction

One of the major constraints to profitable livestock production is the limited feed supply throughout the year. Rapid population growth, coupled with rising housing demand, limits the availability of suitable land for feed production. The growth of livestock depends heavily on the forage crop planting and the establishment of pastures. Providing the necessary feed is crucial to meet animal requirement for growth and production. The use of non-traditional feeds, such as agricultural by-products, along with feed sources, may provide farmers with diversified feeding options (Nkosi and Nkosi, 2010) [24].

Wild reed plant (RP) in Iraq is a great source of forage because it is widely distributed throughout the country, and ruminants find it tasty when converted into straw or silage, especially the small soft parts that contain high protein and other nutrients (Al-Nadawi and Al-Samarrae 2024) [2]. Raheef (2007) [30] showed that *in vitro* dry matter (IVDMD) and organic matter digestibility (IVOMD) of RP can be improved by chemical and biological treatments. Al-Saady, (2009) [3].

Whey is a residual by-product resulting from the processing of milk in derived products, and as fresh has low commercial value, and its excess can cause serious problems of environmental pollution (Silva, et. al., 2018) [40]. In anaerobic environment, whey may be another product producing organic acids and lactic acid (Schumcher, et. al., 2019) [39]. Cajarville *et al.* (2012) [8] reported the use of additives such as whey and molasses in the production of silage. Queiroz *et al.* (2013) [29] confirmed that these additives inhibit or reduce the growth and activity of undesirable microorganisms within the silo.

Molasses is a by-product of sugar industry. It is commonly used as fermentation promoter to promote the growth of lactic acid bacteria (LAB) in silage (Gao, et, al., 2021) [11].

Molasses is a cheap source of water-soluble carbohydrates (WSC), which are essential substrates for the activity and growth of LAB, improving fermentation in silage. This study aims to evaluate the effect of adding different levels of liquid whey and molasses on improving the quality and nutritive value of wild reed silage.

Materials and methods

Preparation of wild reed silages

Samples of wild reed silages (RS, 500-600 g) were prepared in a laboratory. Wild reed plants (RP, 50.08% DM) were chopped into 1.5-2 cm of length. Liquid whey (LW) as a natural source of LAB (3.5×10^6 cfu/ml) obtained from local Animal breeder, was added to ensure introducing LAB to RP at zero, low and high levels (0, 1×10^5 and 1×10^6 cfu/g FM). Number of LAB was counted on the deMan, Rogosa, and Sharpe agar prepared and sterilized according to the manufacturer's instructions after incubation anaerobically at 37°C for 48 h (Addaha, et. al., 2010) [1].

Cane molasses (M) obtained from the Etihad Food Industries CO. Ltd. in Babylon Province was added as a source of WSC at levels of 4, 6 and 8%. Urea was added to all samples as a source of nitrogen (N) at 1%. Molasses and urea were added on DM basis of RP. Additives were diluted with a quantity of water enough to reduce DM content of ensiled materials to about 35%. Accordingly, nine RP silages were prepared with five replicates for each.

Samples of RS were tightly packed in double nylon bags, well compacted to exclude the air, sealed and kept in pit silos for 60 days. By the end of this period samples were transferred to laboratory to estimate nutritional value characteristics. The chemical composition of wild reed plant and additives is shown in table 1.

Table 1: Chemical composition¹ of reed plant and additives (%) on DM basis

Nutrients	Reed plant	Liquid whey	Molasses	Urea
DM	50.58	-	68.75	-
Ash	15.76	-	12.23	-
CP	9.03	1.64	2.20	287.5 *
EE	3.29	-	0.69	-
CF	47.82	-	0.10	-
NDF ²	70.67	-	-	-
ADF ²	49.25	-	-	-
ADL ²	23.45	-	-	-
IVDMD ³ , %	32.87	-	-	-
IVOMD ³ , %	37.01	-	-	-

Chemical analyses were carried out according to the methods of AOAC (2005) [4]. DM, dry matter; CP, crude protein; EE, ether extract; CF, crude fiber; ² Cell wall components including; neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to the method of Goering and Van Soest (1970) [12]; ³ *In vitro* dry and organic matter digestibilities. *46 × 6.25.

Determination of sensory characteristics

The sensory characteristics of the silage including color, smell, texture and the presence of molds were determined as described by (Saeed, 2015) [34]. Green color was adopted with the use of different gradations to describe the color of RS. The smell was determined directly after opening each sample with the use of diluted or concentrated to indicate

the severity of the smell emitted from each RS sample. Determination of texture was based on the condition of the samples in terms of the shape or they took, aggregated or not with reference to the level of aggregation. Presence, place and extent of fungi growth was expressed by - or + signs.

Qualitative characteristics and *in vitro* digestibility

Dry matter (DM) loss was calculated as a percentage of the difference in the total DM content of the silage samples, depending on the sample's weight and the percentage of its DM content before and after ensiling. The Flieg point (Fp) as numerical assessment of the silage quality was estimated according to the equation derived by Kilic (1984) [17] as follows:

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

The buffering capacity (BC) was estimated milliequivalents of base required to change the pH of silage samples (100 g DM) from 4 to 6 (Playne and McDonald, 1966) [27]. Briefly, 5 g of silage was mixed with 100 ml of distilled water for 2 minutes. The mixture was filtered through filter paper and 50 ml of filtrate was used to determine the pH, then 0.1M solution of HCl was added to release carbonate as CO₂ and lower pH to 3. Then volume of 0.2M solution of NaOH was added to raise the pH of the filtrate to 4 (R1). Followed by volume of 0.1M solution of NaOH was added to raise the pH to 6 (R2). The BC was calculated using the following equation:

$$BC \text{ (mEq/100g DM)} = 390 \div (R1-R2) \text{ ml} \times DM\% \text{ of the sample.}$$

The Aerobic stability (AS) of the silages was estimated directly at opening the bags in which reed plants were ensiled. About 120 g of fresh silage was placed in a 500 ml well isolated plastic container. A glass thermometer was installed through one of small holes made in cheese cloth that replaced the lid of the container penetrating the silage mass to measure the changes in the temperature caused by the attack of aerobic microorganism. The AS is the time that passes until the temperature of silage rises by 2°C compared to the ambient temperature (Levital, et al., 2009) [19].

The *in vitro* digestibility was determined according to the method of Tilley and Terry (1963) [19]. Briefly, 0.5 g of silage sample was placed in sterilized glass tubes with 10 ml of rumen liquid and 40 ml of artificial saliva and incubated in a water bath for 48 hours at 38 °C with CO₂ pumped once every 12 hours. The content was filtered and the precipitate was dried at 105 °C for 24 hours. The samples were then cooled, weighed and transferred to muffle furnace at 550°C for 4 hours to determine the remaining organic matter. The IVDMD and IVOMD were calculated according to the following equations.

$$IVDMD\% = [(DM \text{ sample} - DM \text{ Residue (sample - Blank)}) / DM \text{ sample}] \times 100$$

$$IVOMD\% = [(OM \text{ sample} - OM \text{ Residue (sample - Blank)}) / OM \text{ sample}] \times 100$$

Data obtained were analyzed as a factorial experiment in completely randomized design by analysis of variance using statistical analysis system (SAS, 2010) [38].

Results and Discussion

Sensory characteristics

Table 2 shows the sensory characteristics of wild reed silage samples as affected by the effect of adding different levels of liquid whey (LW) and molasses (M). The results revealed that. The color was ranged from dark green to greenish yellow. Saeed *et al.* (2021) [37] obtained similar results for palm leaves silage prepared by adding liquid whey and molasses. Bakare *et al.* (2023) [6] reported that a change in

color from natural green to light green indicates silage quality, while a change from green to brown or very dark indicates poor silage quality, and that this color change may be due to the addition of molasses. Handriati *et al.* (2019) [13] indicated that the dark brown color of molasses may change the natural green color into a darker color in cassava leaf silage. Rostini (2017) [32] reported that color changes during silage fermentation can be affected by temperature, rising temperatures may lead to a color change from green to brown. Babayemi (2009) [5] considered maintaining the green color of the leaves during fermentation provides evidence of good quality silage.

Table 2: Sensory characteristics of wild reed silages

Level of LW	0			1×10 ⁵ cfu/g FM			1×10 ⁶ cfu/g FM		
Level of M	4	6	8	4	6	8	4	6	8
Color	DG	GY	DG	DG	GY	GY	GY	GY	GY
Odor	DA- DFV			DFV-CFV			DFV-CFV		
Texture	Good	Good	Good	Good	Good	Good	Good	Good	Good
moldiness	+	+	-	-	-	-	-	-	-

LW: liquid whey; M, molasses; DG, dark green; GY, greenish yellow; DA, diluted ammonia; DFV, diluted fruit vinegar; CFV, concentrated fruit vinegar; +, -, Presence or absence of mold.

The odor emitted from RS samples ranged from a diluted ammonia odor to diluted fruit vinegar in the RS samples prepared without adding LW. The ammonia odor emitted from the silage may be due to protein degradation by aerobic bacteria, and this is an indicator of poor fermentation due to the pH not being sufficiently low to inhibit the activity of these bacteria. Kung, et. al. (2018) [18] mentioned that a decrease in pH leads to the production of volatile fatty acids, which gives the silage a sour vinegar or fruit vinegar smell. In RS samples prepared with both levels of LW, the odor of diluted to concentrated fruit vinegar was emitted. This is consistent with the findings of Saeed (2008) [33] who observed an odor of fermented fruit in wheat straw silage treated with molasses.

Regarding the texture, all silage samples were aggregated and had a good texture. This indicates an improvement in the fermentation profile of the RS samples, attributed to the role of adding liquid whey and molasses. Similarly, Saeed *et al.* (2021) [37] reported that adding LW and M to date palm leaves silage improved the sensory profile, where all samples appeared aggregated. Bakare *et al.* (2023) [6] indicated that the addition of molasses improved the texture of cassava leaf silage. Sufficient compaction of ensiled materials may also help maintain the aggregation of the silage samples by binding plant materials and additives together.

The results revealed the absence of moldiness in all silage samples, especially those prepared with addition of both additives. This is due to good fermentation and a rapid drop in pH, which in turn inhibited the activity of aerobic microorganisms responsible for moldiness. Saeed and Abo-Ellul, (2018) [36] demonstrated that enhancing the ability of LAB to metabolize WSC in inoculated wheat straw silage contributes to increase the production of lactic acid and other organic acids during fermentation. This leads to a rapid drop in pH and inhibition of the activity of aerobic silage organisms. McDonald *et al.* (1991) [21] reported that rapid decrease in pH and absence of oxygen lead to a decrease in yeast and mold numbers and inhibition of their activity.

Silage quality and nutritive value

Main effect of liquid whey and molasses levels

Table 3 shows the main effect of adding different levels of liquid whey (LW) and molasses (M) on the nutritive value of wild reed silage (RS). Results revealed that adding LW at low and high levels, intended to introduce LAB at 1×10⁵ and 1×10⁶ cfu/g FM, led to a significant ($P<0.01$) decrease in the dry matter (DM) loss to 7.97 and 5.10% respectively as compared with 10.42% in RS samples prepared without adding LW.

Table 3: Main effect of liquid whey and molasses levels on nutritive value characteristics of wild reed silages (mean ± SE)

Items	Liquid whey, LW, cfu/g FM			Molasses, M, %			P	
	0	1 × 10 ⁵	1 × 10 ⁶	4	6	8	LW	M
DM loss, %	10.42 ^b ± 0.70	7.97 ^b ± 0.52	5.10 ^c ± 0.26	8.85 ^a ± 0.77	7.80 ^{ab} ± 0.64	6.84 ^b ± 0.83	**	**
Fp, pts.	61.08 ^c ± 2.18	75.24 ^b ± 3.13	86.70 ^a ± 1.63	59.11 ^c ± 5.07	73.89 ^b ± 4.21	90.02 ^a ± 1.12	**	*
AS, hrs.	156.73 ^a ± 5.56	143.33 ^c ± 3.11	145.26 ^b ± 5.32	144.06 ^b ± 5.78	150.26 ^a ± 3.96	151.00 ^a ± 5.02	**	**
BC	65.00 ^a ± 7.34	56.33 ^a ± 6.09	28.18 ^b ± 2.66	66.14 ^a ± 5.18	46.36 ^b ± 3.65	37.01 ^b ± 2.17	**	**
IVDMD, %	32.88 ^c ± 0.32	35.15 ^b ± 0.35	37.76 ^a ± 0.46	34.63 ^b ± 0.56	34.96 ^b ± 0.61	36.20 ^a ± 0.70	**	**
IVOMD, %	37.40 ^c ± 0.41	39.20 ^b ± 0.59	41.64 ^a ± 0.50	38.44 ^b ± 0.38	38.97 ^b ± 0.67	40.83 ^a ± 0.69	**	**

Means having different letters at the same row are significantly different at: * ($P<0.05$), ** ($P<0.01$). cfu, colony forming units; FM, fresh matter; LW; liquid whey; M; molasses; DM loss, dry matter loss, %; Fp, Fleig points; pts, points. AS, aerobic stability; hrs, hour; BC, buffering capacity, meq NaOH/100 g DM; IVDMD, *in vitro* dry matter digestibility, IVOMD, *in vitro* organic matter digestibility

The results showed a significant ($P<0.01$) increase in the Fleig points (Fp) from 61.08 in RS samples prepared without adding LW to 75.24 and 86.70 in those prepared with low and high levels of LW respectively. The higher Fp may be due to improved RS fermentation resulted from the increased LAB number with the increase LW level, which leads to a decrease in pH through the production of lactic acid and also leads to a decrease in DM loss. Therefore, the decrease in pH was responsible for the higher Fp. This is consistent with Kareem and Saeed (2021) [16] in the ensiled corn residuals. Kilic (1984) [17] reported that the Fleig point depends on the DM level of the ensiled materials and the pH changes during fermentation.

Regarding the effect of adding different level of LW on aerobic stability (AS), the results revealed that AS was significantly ($P<0.01$) decreased from 156.73 in RS samples prepared without LW to 143.33 and 145.26 hours in those prepared with low and high levels of LW respectively. This is consistent with Negron (2006) [23] who reported that adding whey to grass and Bermuda grass silage reduced the aerobic stability of the silage. However, Nkosi (2003) [26] reported improved aerobic stability in mango silage treated with liquid whey.

The results showed that a significant ($P<0.01$) decrease in buffering capacity (BC) from 65 and 56.33 in RS samples prepared without adding LW and those prepared with low level of LW respectively, to 28.18 meq NaOH/100 g DM in RS samples prepared with high level of LW. The BC is closely related to the pH, where low pH leads to a decrease in the BC due to the presence of sufficient amounts of organic acids produced by LAB provided by the high LW level. Mordenti, et. al., (2021) [22] mentioned to similar relationship between acidity and BC.

To demonstrate the effect of adding different levels of LW on *in vitro* digestibility on dry matter (IVDMD) in RS samples, the results showed a gradual significant increase ($P<0.01$) in IVDMD values. The values were increased from 32.88 in RS samples prepared without LW to 35.15 and 37.76% when LW was added at low and high levels, respectively. This increase may be due to the improved fermentation process as affected by the addition of LW, which leads to partial decomposition of cell wall components, thus increasing the digestibility. Cajarville *et al.* (2012) [8] reported that increasing the whey level resulted in a linear increase in DM decomposition capacity with increasing the readily decomposable fraction, it was noted that as the whey level increased to 100 g/kg, the positive effect on DM decomposability remained with increased effluent losses. Therefore, the whey level as an additive should only be used with feeds with low moisture content. Huisden *et al.* (2012) [14] demonstrated that silage fermentation can improve the digestibility of cell wall components, providing more soluble sugars for lactic acid production.

Similarly, the *in vitro* organic matter digestibility (IVOMD) was increased ($P<0.01$) due to addition of LW at both levels. This increase in IVOMD may be due to the continuous improvement in silage fermentation and the production of more organic acids such as a response to providing fermentation media with more LAB number with the increase in the level of LW. This result is consistent with what Bautista-Trujillo *et al.* (2009) [7] found who observed a significant improvement ($P<0.05$) in the IVOMD of corn plant ensiled with whey.

Regarding the main effect of adding different levels of molasses (M) on the nutritive value of wild reed silage (RS), the results showed a significant decrease ($P<0.01$) in DM loss to 6.84 in RS samples prepared with higher M level as compared with 8.85% in those prepared with lower M level. This improvement in DM loss may be attributed to the increased WSC content in the fermented material, which improves fermentation quality by providing soluble sugars to stimulate the fermentation process and reduce DM loss. Molasses is most frequently used as WSC source. Kanengoni *et al.* (2016) [15] observed that adding molasses with whey and exogenous enzymes improves fermentation and reduces DM and CF levels.

The results showed a significant increase ($P<0.05$) in the Fleig point (Fp), mean estimated values in RS samples prepared with 4, 6 and 8% level of M were 59.11, 73.89 and 90.02 points respectively. This increase in the Fp can be explained on basis of the continuous improvement in RS fermentation due to the increased level of added soluble sugars, which enhances fermentation and improves silage quality. This is in addition to the close relationship between silage fermentation and the level of soluble sugars, where the addition of soluble sugars leads to an increase in the Fp, as well as the correlation of the Fp with the decrease in pH resulting from the addition of molasses. Saeed *et al.* (2021) [37] observed an increase in the Fp in date palm leaves ensiled with increased levels of molasses.

The results of the current study revealed that higher levels of molasses significantly improved ($P<0.01$) the AS. Samples of RS prepared with 6 and 8% of M sustained for longer ($P<0.01$) time as compared with those prepared with lower M level. The improvement in AS may indicate improved silage fermentation as affected by providing silage microorganisms with increased amounts of soluble sugar. Wang *et al.* (2025) [43] indicated a significant improvement ($P<0.01$) in the mixed silage of zucchini peel residues and corn stalks to which molasses was added. However, Dong *et al.* (2020) [9] noted that adding fermentable carbohydrates, such as glucose or molasses, can enhance primary fermentation but reduce aerobic stability during exposure to air. Qiu *et al.* (2024) [28] reported that the availability of nutrients such as soluble sugars creates a favorable environment for aerobic microorganisms, promoting their growth and reproduction.

The difference in the results of previous studies may be to the nature of the fermentation as influenced by the metabolic pathways by which LAB ferment the added source of WSC. The result obtained in the current study participates in that difference. The slight difference between AS recorded in RS samples prepared with 6% and those prepared with 8% level of molasses (159.26 vs. 151 hours) may be an indication on the type of fermentation dominated during ensiling.

The results showed a significant decrease ($P<0.01$) in the buffering capacity (BC) values with increasing M levels. The BC values were 66.14, 46.36 and 37.01 for RS samples prepared with 4, 6 and 8% levels of M, respectively. Similar trend of lower BC values in corn cobs silage were observed by Saeed and Muhamad (2017) [35] with increasing date molasses levels. This decrease may be attributed to the acidic environment probably created as higher amounts of soluble sugars were provided for LAB to produce more acid, lowering the pH and thus decreasing the buffering capacity. Mordenti *et al.*, (2021) [22] stated that adding easily

fermentable sugars to molasses stimulates the activity of beneficial bacteria, represented by LAB, which improves the buffering capacity.

With regard to effect adding different levels of molasses (M) on *in vitro* dry matter digestibility (IVDMD) in wild reed silage (RS) samples, the results revealed that higher ($P<0.01$) IVDMD was associated with higher level of M. Mean IVDMD values were 34.63, 34.96, and 36.20 for RS samples prepared with 4, 6, and 8%, level of M, respectively. The association of significant improvement in IVDMD with RS samples prepared with higher level of molasses can be explained on basis of improved fermentation pattern leading to the decomposition of cell wall components. El-Talty *et al.* (2015) [10] attributed the improvement in IVDMD to the improved decomposition of plant cell walls during silage fermentation.

As expected, *in vitro* organic matter digestibility (IVOMD) adopted similar trend, where higher ($P<0.01$) IVDMD was recorded in RS samples prepared with higher level of molasses (M). This increase may indicate that the higher M level was sufficient in comparison with other lower levels for the LAB and other silage microorganisms to benefit creating acidic condition inside silage mass capable of cell

wall degradation. Verma and Prakash (1996) [42] confirmed that adding molasses at a rate of more than 6%, leads to an increase in the digestibility of cellulose.

Interaction effect between levels of liquid whey and molasses

The effect of the interaction between liquid whey (LW) and molasses (M) levels added at ensiling on the quality characteristics and nutritive value of wild reed silage (RS) are shown in table 4. Statistical analysis revealed that lower ($P<0.05$) DM losses were associated with RS samples prepared with adding high levels of both LW and M. This is consistent with the findings of Cajarville *et al.* (2012) [8] in which, the use of additives such as liquid whey and molasses reduced the silage DM decomposition capacity resulting in a lower DM loss. This response was somewhat expected due to the presence of LAB in the fermentation medium. Therefore, RS samples prepared with adding low level of LW together with 8% level of M also showed lower DM loss. Moreover, the highest ($P<0.05$) DM loss was recorded in RS samples prepared without LW and with the lowest M levels.

Table 4: Interaction effect between liquid whey and molasses levels on nutritive value characteristics of wild reed silages (mean $\pm$ SE)

Liquid Whey level	0			1×10^5 CFU/g FM			1×10^6 CFU/g FM			P
Molasses level	4	6	8	4	6	8	4	6	8	
DM loss, %	11.43 ^a $\pm$ 1.04	10.31 ^{ab} $\pm$ 0.49	9.53 ^{ab} $\pm$ 1.87	9.01 ^{abs} $\pm$ 1.22	8.31 ^{bcd} $\pm$ 1.38	6.59 ^{cde} $\pm$ 0.67	6.13 ^{de} $\pm$ 0.38	4.78 ^e $\pm$ 0.31	4.40 ^e $\pm$ 0.24	*
Fp, pts.	27.25 ^e $\pm$ 7.79	68.31 ^{cd} $\pm$ 12.26	87.68 ^{ab} $\pm$ 2.52	64.76 ^d $\pm$ 4.83	71.07 ^{bcd} $\pm$ 2.24	89.90 ^a $\pm$ 2.08	85.31 ^{ab} $\pm$ 2.79	82.30 ^{bcd} $\pm$ 1.90	92.48 ^a $\pm$ 1.68	**
AS, hrs.	174.60 ^a $\pm$ 0.50	168.00 ^b $\pm$ 0.20	127.60 ^c $\pm$ 0.81	127.00 ^c $\pm$ 0.44	151.00 ^c $\pm$ 0.89	152.00 ^c $\pm$ 0.94	130.60 ^d $\pm$ 0.24	131.80 ^d $\pm$ 0.37	173.40 ^a $\pm$ 0.74	**
BC meq NaOH/100 g DM	92.81 ^a $\pm$ 8.83	58.20 ^{bc} $\pm$ 2.56	44.00 ^{cd} $\pm$ 2.77	77.26 ^{ab} $\pm$ 7.26	52.05 ^{bcd} $\pm$ 2.06	39.69 ^{cd} $\pm$ 2.00	28.37 ^{cd} $\pm$ 1.08	28.84 ^{cd} $\pm$ 1.63	27.35 ^d $\pm$ 1.74	*
IVDMD, %	32.73 ^f $\pm$ 0.17	32.46 ^d $\pm$ 0.35	33.46 ^{ef} $\pm$ 0.89	34.36 ^{def} $\pm$ 0.35	35.15 ^{cde} $\pm$ 0.82	35.96 ^{bcd} $\pm$ 0.42	36.80 ^{bc} $\pm$ 0.56	37.29 ^b $\pm$ 0.52	39.19 ^a $\pm$ 0.30	*
IVOMD, %	37.19 ^d $\pm$ 0.27	36.93 ^d $\pm$ 0.22	38.09 ^d $\pm$ 0.39	38.03 ^d $\pm$ 0.28	38.60 ^{cd} $\pm$ 0.85	40.98 ^b $\pm$ 0.93	40.12 ^{bc} $\pm$ 0.48	41.39 ^b $\pm$ 0.75	43.43 ^a $\pm$ 0.65	*

Means having different letters at the same row are significantly different at: * ($P<0.05$), ** ($P<0.01$)

FM, fresh matter; CFU, colony forming units; DM, dry matter Fp, AS, aerobic stability; h, hour; Fleig points; pts, points

BC, buffering capacity, meq NaOH/100 g DM; miliequivalent NaOH/ 100 g dry matter

IVDMD, *in vitro* dry matter digestibility

IVOMD, *in vitro* organic matter digestibility

The results of interaction effect showed that higher ($P<0.01$) Fleig points (Fp) values were estimated in RS samples prepared with adding both levels of LW and higher M level. However, RS samples prepared without adding LW together with higher M level also showed high Fp values (87.68 pts). This indicated that Fp may be affected by level of molasses as fermentation stimulant more than level of LW as a natural source of LAB. Kilic (1984) reported that the Fleig point depends on the DM level of the ensiled materials and the changes in pH during fermentation. The addition of molasses enhances the nature of fermentation, adding soluble sugars to silage enhances the activity of LAB, which ferment sugars into organic acids, especially lactic acid, leading to lower the pH. Even though, in RS prepared with high level of LW, high Fp was recorded regardless to the level of M. This case may be due to the presence of high number of LAB that makes use of even the lower level of

molasses. higher in With regard to effect of interaction between level of LW and M on aerobic stability (AS). The results revealed that RS samples prepared without LW plus low M level (174.60 hrs.) and those prepared with high level of LW plus higher M level (173.40 hrs.) withstand for longer ($P<0.01$) period against the attack by aerobic microorganisms. Higher AS was evidenced by the rise of temperature inside those samples 2 °C above the environment temperature (Levital, et. al., 2009) [19]. This result cannot be explained away from the nature and the end product of the silage fermentation. Kanengoni *et al.* (2016) [15] observed that ensiling corn cobs with whey led to stabilization of aerobic stability. Weinberg and Muck (1996) reported that the addition of heterofermentative LAB such as *L. buchneri* improved AS of silage.

The results showed that RS samples prepared with high level of LW regardless to M levels were characterized with lower ($P<0.05$) buffering capacity (BC) with values ranging from 28.84 to 27.35 meq NaOH/100 g DM. According to Martinez-Fernandez, et. al., (2013) BC represents extent of resistance of materials to changes in pH. Hence, lower BC values were expected since high level of LW provided fermentation media with additional numbers of LAB, fermenting WSC to lactic acid and lowering the pH. Therefore, the higher level of molasses as a source of WSC added at ensiling resulted in the lower BC values. Similarly, Saeed and Muhammad (2017) [35] observed lower BC in corn cobs ensiled with higher level of date molasses. The authors attributed such case to providing silage microbes with

soluble sugars and stimulating organic acids producing silage fermentation.

The results of the current study revealed that higher ($P<0.05$) IVDMD values were associated with RS samples prepared with high levels of both LW and M. This increase may be due to the role of organic acids produced by LAB, which lead to the breakdown of fiber, thus increasing their digestion rate. Cajarville *et al.* (2012)^[8] indicated that adding whey to silages led to an increase ($P<0.03$) in the degradation of DM. The role of providing ensiled materials with LAB was extended to lower level of M. Lower IVDMD values were recorded in RS samples prepared without LW regardless to M levels. Similar trend was shown with regard to IVOMD. The role of acidic environment probably resulted from the presence of lactic acid that possibly participated in improved IVOMD was more pronounced. Nkosi *et al.* (2012)^[25] confirmed that whey and molasses are effective in improving fermentation properties and the IVOMD.

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