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Utilization of sugar cane juice as additive for guinea grass silage making in eastern coast of Tanzania

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Abstract

A study was conducted to determine effectiveness of sugar cane juice as water-soluble carbohydrate additive for guinea grass silage making. Results indicated that there was a dilution effect in terms of dry matter and crude protein contents of guinea grass material with increase in levels of sugar cane juice before ensiling. Use of sugar cane juice increased level of water-soluble carbohydrate content of forage material before ensiling. Dry matter loss was highest in the control as compared to sugar cane juice treated silages. Inclusion of sugar cane juice in guinea grass silage making, limited crude protein losses as compared to untreated silage. Furthermore, results indicated that inclusion of sugar cane juice in ensiled guinea grass resulted into more extensive fermentation depicted by higher lactic acid concentration than in untreated silage. Guinea grass silages that resulted from treatments with sugar cane juice were more acceptable by crossbred dairy cows than untreated guinea grass silage. It was concluded that inclusion of sugar cane juice by 10% of fresh weight of guinea grass produces good quality and most acceptable silage for crossbred dairy cows feeding.

Key words: Ensiling; guinea grass; silage; sugar cane juice; water-soluble carbohydrate

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Introduction

Generally, dairy animal production in eastern coast of Tanzania is challenged by seasonal availability of forage. There is shortage of feeds during the dry season while surplus forage material exists during the rainy season. In order to alleviate the dry season feeding problem for dairy cattle, it has been considered plausible to conserve the surplus forage material that exists during the rainy season. Hay and silage could be appropriate methods of forage conservation. Hay making in eastern coast of Tanzania is rather difficult because in most cases the optimum period for hay making coincides with wet season which limits sun-drying of forage material. Silage making could therefore be appropriate because the technique is less weather dependent (Wilson and Bringstock, 1981). However, conservation of forage in form of silage is not common to smallholder dairy farmers in eastern coast of Tanzania due to lack of simple methods of silage making. Guinea grass (*Panicum maximum*) is a potential grass species to support dairy production in eastern coast of Tanzania. Its dry matter production could reach up to 12 tons/ha (Mkiwa, 1986). Nevertheless, large proportion of dry matter is wasted during the dry season as the grass becomes dry, coarse, high in crude fibre and low in water-soluble carbohydrates. A combination of these factors result in delayed fermentation and proliferation of clostridia organisms during silage making. To alleviate the limitation of low water-soluble carbohydrates, additives that stimulate fermentation such as molasses are recommended as a pre-requisite for ensilage of tropical forage materials. Even though, availability of molasses for smallholder dairy farmers in eastern coast of Tanzania is hampered by high transportation costs from sugar factories that are far from smallholder dairy farmers of eastern coast of Tanzania. It is therefore credible to consider alternative sources for water-soluble carbohydrates such as sugar cane juice. Most of

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smallholder farmers in eastern coast of Tanzania grow sugar canes for chewing and local brew making. Therefore sugar cane juice could be locally available for use in silage making.

The aim of this study was to determine the effectiveness of sugar cane juice as water-soluble carbohydrate additive for guinea grass silage making.

Materials and Methods

Forage material

Guinea grass (*Panicum maximum*) was used in this study because it is abundant in potential areas for dairy production in coastal areas of Tanzania. One hector of guinea grass was established on station in April 2000. Triple Super Phosphate fertilizer was applied at rate of 150 kg P_2O_4/ha before planting whereas urea was applied after weeding at rate of 200 kg N/ha. Harvesting was done in July 2000 when grasses were about 50% blooming.

Sugar canes used in this study were purchased from local farmers near the station. It was a local sugar cane variety commonly known as ‘’*Bungara*” characterized with pale green rind and soft pith. This variety is normally established for chewing and not for sugar production.

Additive

Sugar cane juice was used as additive in this experiment. It was obtained by pressing sugar canes in a wooden sugar cane press prepared locally. A tool operates in a gear system where sugar cane is placed between driving and driven gears. As the gears rotate they consequently squeeze the sugar cane juice that consequently collected in a bucket below the gear system.

Silos

Plastic bucket silos were used in this study. The mean diameter of buckets was 31 cm and average height was 35 cm. Four earth-pit silos of dimensions 1m x 1m x 1m each with a capacity of holding up to 200 kg forage material were prepared. Earth-pit silos kept silage to supply the animals during acclimatization period as well as lag phase periods.

Ensiling process

Harvested forage materials were chopped using machetes and then mixed with appropriate sugar cane juice level. The treatments tested were T1 (forage material ensiled without sugar cane juice), T2 (forage material treated with 5% sugar cane juice), T3 (forage material treated with 10% sugar cane juice) and T4 (forage material treated with 15% sugar cane juice). The bucket silos used per treatment were 10 and about 5 kg of forage material was ensiled in each silo. A polyethylene bag containing 5 kg of sand was inserted in each silo after ensiling so as to exert pressure throughout the preservation period. The preservation period was 90 days.

Experimental animals

Five cross-bred (Friesian x Boran) dairy cows were obtained from smallholder dairy farmers around the research centre. The body weights of cows were between 352 to 377 kg. Prior to experimental period, the animals were dewormed using *Levamizole hydrochloride* (Nilzan). The animals were allowed to graze during the day and confined at night. In the morning the animals were confined in individual stalls where they were supplied with the silage to be tested.

Organoleptic tests

Immediately after opening each silo, the silage material was assessed in terms of appearance, smell and texture. Assessment was done by a panel of 10 individuals; each marked a score grade card for each treatment.

Preparation of silage samples for analysis

The silage from each silo was thoroughly mixed and then a sample of about 500g was taken. The sample was sufficient to provide enough sub-samples required for chemical analyses and determination of pH, concentration of fermentation products, ammonia nitrogen and *in vitro* dry matter digestibility. The samples were put in polyethylene bags and stored in deep freezer at –10ºC until when they were used for laboratory work.

Determination of pH

Samples weighing 40 g from each silo were soaked in 200 ml of cool distilled water for 12 hours. The mixture was then filtered and supernatant divided into 4 aliquots for determination of pH using pH meter.

Ammonia nitrogen determination

Frozen samples were used for determination of ammonia nitrogen. The samples weighing 5 g from each treatment were put in separate digesting tubes followed by addition of 75 ml of cool distilled water. To determine the amount of free nitrogen contained in silage samples, the digesting tubes with their contents were subjected to steam distillation. The equipment used was Kjeltec System 1002 distilling unit where ammonia nitrogen was collected trapped in boric acid. Titration with hydrochloric acid was done to determine the amount of ammonia nitrogen tapped in boric acid. The amount of ammonia nitrogen present in silage sample was expressed as the ratio of ammonia nitrogen obtained by steam distillation to total nitrogen content of silage multiplied by 100. Routine Kjedahl method

(Association of Official Agricultural Chemists, 1990) was followed in determination of total nitrogen.

Determination of volatile fatty acids

Samples weighing 1g from each silo were put in separate conical flasks. Then, 5 ml of distilled water was added in each conical flask followed by shaking for 20 minutes. Silage juice was drawn from conical flasks into test tubes and centrifuged at 3000 revolutions per minute for 5 minutes. Then 0.5 µl of supernatant was drawn and mixed with isobutyric acid (internal standard) and 20% phosphoric acid as an acidifying agent. The ratio was 8:1:1 (supernatant: internal standard: acid). Then 0.25 µl of the mixture was injected in gas chromatography (GC) equipment for determination of volatile fatty acids (VFA).

Lactic acid determination

Since lactic acid is not volatile, methylation was done. Centrifuged sample (0.5 ml) was pipetted into a test tube followed by 0.5 ml of 10mM malonic acid (internal standard), 0.4 ml of 50% sulphuric acid (H_2SO_4) and 2.0 ml of ethanol. The contents were mixed well by stirring and incubated in water and 1 ml of chloroform was added before meticulous mixing. Then 2 µl of the mixed content was injected into a GC equipment using a wipe syringe for determination of lactic Acid. The GC was operated isothermally at 125˚C (Column oven), 125˚C (injection or inlet) and 170˚C (detection).

Determination of dry matter and chemical composition of samples

Dry matter of samples was determined by freeze-drying while samples for determination of chemical composition were air dried in a well ventilated room. Dried samples were ground to pass through 1 mm screen in a hammer mill. Samples were chemically analysed for determination of crude protein (CP) according to standard procedures (Association of Official Agricultural Chemists, 1990). Acid Detergent Fibre (ADF) of samples was determined as described by Gőering and Van Soest (1970). Water-soluble carbohydrates (WSC) contents of samples were determined spectrophotometrically according to Thomas (1977). *In vitro* dry matter digestibility of samples was determined according to Tilley and Terry (1963).

Experimental design

There were four treatments i.e., control (no additive), 5% sugar cane juice, 10% sugar cane juice and 15% sugar cane juice. Each treatment was allocated to a silo in a completely randomised manner. On the other hand, Latin square design was used in determination of intake rate between treatments.

Statistical analysis

Data on chemical composition as well as fermentation products and intake rate were analysed based on treatment effect. General Linear Model (GLM) procedures of statistical analysis system (SAS, 1988) with sum of square (SS1) option for analysis of variance was used in analysis of data collected. Mathematical model used was as follows:

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

Where; Y_{ij} = Silage quality attributed to different levels of sugar cane juice

μ = Fixed general effect

A_i = Effect of ith additive

e_{ij} = Random variation

Acceptability test

The acceptability of silage by the animals was evaluated in terms of intake rate. Five cross-bred cows (Friesian × Boran) owned by smallholder dairy farmers were used. The animals were allowed to graze during the day and were confined in individual stalls where they were provided with test silage. The animals were provided with silage for seven days before data collection (preliminary period) and lag phase between treatments was three days. Each treatment was fed to the animals for 7 days. Each animal was given access to silage for ten minutes per meal. The amount of silage given and the amount left after 10 minutes were recorded. Then the animals were given free access to the remainder silage after record taking. The intake rate of silage was calculated as follows:

Intake rate (g/min) = Amount of silage eaten within ten minutes/10 minutes

Finally the intake rate was expressed in terms of dry matter (gDM/minute) by multiplying the weight of fresh silage eaten by corresponding dry matter content of each treatment.

Dry matter loss

The amount of dry matter lost in the silos was calculated by considering the difference between the DM contained in the original ensiled material and the DM of silage recovered. The dry matter loss was calculated as follows:

KgDM loss = kgDM of ensiled forage – kgDM of recovered silage

Whereby;

KgDM of recovered silage = kgDM of good silage + kgDM of spoiled silage

The DM loss was finally expressed as percentage of DM present in the original forage material to be ensiled.

Results and Discussion

Results shown in Table 1 indicated that there was a dilution effect in DM and CP contents with increase in

levels of sugar cane juice. DM and CP in sugar cane treated forage material were lower than in untreated forage material. This trend was similar to the one reported by Kavana (1998) when dealing with Guatemala grass. Sugar can juice had low DM and CP content that consequently affected the contents of the mixture. Similar trend was observed in fibre contents of forage material before ensiling. Use of sugar cane juice increased significantly ($P<0.05$) water soluble carbohydrate contents of forage material. This was attributed to high contents of sugar in sugar cane juice (189 g/l).

Table 1: Effect of sugar cane juice on dry matter, chemical composition and *in vitro* dry matter digestibility of guinea grass before ensiling

Treatment	DM (%)	CP	ADF	NDF	WSC	IVDMD
		gkg^{-1}DM				
T1	40.5	85.0[a]	508.0	660.5[a]	46.5[d]	5540.5
T2	39.7	80.3[ab]	503.6	658.2[b]	54.6[c]	567.7
T3	39.6	74.1[c]	501.2	618.3[c]	60.0[b]	561.1
T4	39.4	77.9[b]	496.6	584.6[d]	67.6[a]	557.3
SEM	3.30	1.89	6.91	1.80	0.80	11.5

T1 = Control, T2 = 5% sugar cane juice, T3 = 10% sugar cane juice, T4 = 15% sugar cane juice, DM = dry matter, CP = crude protein, ADF = acid detergent fibre, NDF = neutral detergent fibre, WSC = water soluble carbohydrates, IVDMD = in vitro dry matter digestibility, [a–d]Means with different superscripts within a column are significantly different ($P<0.05$)

Results indicated a slight improvement in *in vitro* dry matter digestibility in treated forage as compared to untreated forage material. This could be attributed to high water soluble carbohydrates content in treated forage that provided readily available energy for survival and multiplication of rumen cellulolytic microbes responsible for degradation of fibre. This observation however, highlights the possibility of improving digestibility of guinea grass by supplying readily available sugars to microbes. However, results of the present study indicated a slight decrease in *in vitro* dry matter digestibility with increase in levels of sugar cane juice in forage material before ensiling. Ademosun (1974) reported a negative correlation ($r= -0.87$) between ADF content and digestibility of forages. However, results in the present study did not indicate significant ($P>0.05$) difference in terms of ADF between treatments. The reason for slight decrease in DM digestibility in treated forage could be dilution effect of protein that limited performance of microbes. McDonald et al. (1988) reported that if the diet is deficient in protein, or if the protein resists degradation, the concentration of rumen ammonia will be low and the growth of rumen organisms will be slow; in consequence, the breakdown of carbohydrates will be retarded. Raymond (1969) reported low digestibility to be associated with stem fraction as compared to leaf fraction while Minson (1971) observed that in *Chloris gayana*, *Panicum maximum*, and *Panicum coloratum* digestibility was not related to leafiness or floral development.

Results in Table 2 indicated that stem and dead leaves fractions had lower CP, WSC and higher ADF than green leaves. Consequently, stem and dead leaves digestibility was lower than green leaves digestibility. This study indicate that if dairy cattle fed with guinea grass of high fraction of stem and dead leaves could not show better performance due to low digestibility of ration. Therefore, a tendency of smallholder dairy farmers in eastern zone of Tanzania to depend on standing hay contributes to a great extent to low milk production during dry season because stem and dead leaves fractions are high in standing hay that consequently affects digestibility of the ration.

Table 2: Chemical composition and *in vitro* dry matter digestibility of botanical components of guinea grass

Component	CP	ADF	WSC	IVDMD
	gkg^{-1}DM			
Stem	32.4	544.3	43	330.3
Green leaves	85.6	487.5	48	640.9
Dead leaves	22.8	530.2	18	252.7

CP = crude protein, ADF = acid detergent fibre, WSC = water soluble carbohydrates, IVDMD = in vitro dry matter digestibility

Ensilage caused a reduction in DM, CP and WSC contents of forage. The largest changes in CP content occurred in untreated silage (T1) while the smallest change occurred in T3 (Table 3). DM loss could have been attributed to effluent production due to pressure exerted by sand placed on top of ensiled forage material. Largest changes in CP content of untreated forage could have been caused by relatively high pH that enabled existence of putrefactive micro-organisms.

The fibre content of silage was higher than original forage due to loss of soluble materials through effluent that resulted into concentration of cell wall content per dry matter to increase. The observations attained in this study are in agreement with observations made by Sarwatt et al. (1992). However, the NDF contents were not statistically different among treatments. Furthermore, the differences in *in vitro* DM digestibility were not statistically different among the treatments. This could have been attributed to similar contents of CP and residue WSC among treatments that enabled rumen microbial activities to be similar.

Results shown in Table 4 indicated that inclusion of sugar cane juice (T2-T4) in ensiled guinea grass resulted in a more extensive fermentation depicted by the lower pH and higher lactic acid concentration than in untreated forage (T1). There was an increase in lactic acid concentration with increase in levels of sugar cane

Table 3: Effect of sugar cane juice on chemical composition and *invitro* dry matter digestibility of guinea grass silage

Treatment	DM (%)	CP	NDF	ADF	WSC	IVDMD	DM loss (%)
				$gkg^{-1}DM$			
T1	35.8	61.1	707.5	522.5^{b}	12.3	521.2	29.9^{a}
T2	38.4	58.9	727.4	549.8^{a}	10.1	525.7	13.0^{b}
T3	34.8	66.7	727.8	542.5^{ab}	11.1	560.0	13.3^{b}
T4	35.0	63.8	664.9	535.7^{ab}	10.9	557.0	5.5^{c}
SEM	1.47	3.77	33.18	7.08	3.30	10.51	4.39

T1 = Control, T2 = 5% sugar cane juice, T3 = 10% sugar cane juice, T4 = 15% sugar cane juice, DM = dry matter, CP = crude protein, ADF = acid detergent fibre, NDF = neutral detergent fibre, WSC = water soluble carbohydrates, IVDMD = invitro dry matter digestibility, $^{a-c}$ Means with different superscripts within a column are significantly different ($P<0.05$)

Table 4: Effect of sugar cane juice on fermentation products of guinea grass silage

Treatment	pH	NH_3N (%TN)	Lactic acid	Acetic acid	Butyric acid
				$gkg^{-1}DM$	
T1	4.87^{a}	6.7^{a}	20.4^{b}	16.7	4.2^{a}
T2	4.02^{b}	2.7^{b}	34.5^{a}	14.9	2.3^{b}
T3	3.97^{bc}	3.2^{b}	39.1^{a}	15.1	2.3^{b}
T4	3.91^{c}	3.5^{b}	41.7^{a}	17.2	3.0^{b}
SEM	0.064	0.51	4.49	5.2	0.7

T1 = Control, T2 = 5% sugar cane juice, T3 = 10% sugar cane juice, T4 = 15% sugar cane juice, NH_3N = ammonia nitrogen, TN = total nitrogen, SEM = standard error of the means

Table 5: Quality evaluation of silages by organoleptic test scores

Treatment	Appearance	Smell	Texture
T1	1.9^{c}	1.7^{c}	1.9^{c}
T2	2.6^{b}	2.4^{bc}	2.3^{bc}
T3	2.9^{ab}	3.0^{ab}	2.3^{ab}
T4	2.9^{ab}	3.0^{ab}	2.7^{ab}
SEM	0.24	0.20	0.23

T1 = Control, T2 = 5% sugar cane juice, T3 = 10% sugar cane juice, T4 = 15% sugar cane juice, $^{a-c}$Means with different superscripts within a column are significantly ($P<0.05$) different, SEM = Standard error of the means

Table 6: Effect of sugar cane juice on intake rate of guinea grass silage

Treatment	Intake rate (gDM/min)
T1	35.4^{c}
T2	50.8^{b}
T3	70.5^{a}
T4	55.9^{b}
SEM	6.49

$^{a-c}$Means with different superscripts within a column are significantly ($P<0.05$)

juice. Despite of differences in concentration of WSC in pre-ensiled forage material, differences in pH and lactic acid content of silage could be caused by type of lactic acid bacteria that dominated fermentation process. McDonald and Whittenbury (1973) noted that homolactic fermentation of glucose and fructose results in production of one mole of lactic acid while heterolactic fermentation of glucose results in production of one mole of lactic acid and one mole of acetic acid. The same authors commented that the difference in pathways in which soluble carbohydrates are fermented could explain why silages with apparently sufficient WSC content sometimes fail to preserve satisfactorily. Not only WSC that contribute to extent of fermentation of ensiled forage material, hemicellulose component form an important structural carbohydrate in forage which is used as a substrate for silage fermentation (McDonald et al., 1960).

Ammonia nitrogen (NH_3N) was significantly ($P<0.05$) higher in untreated silage (T1) than in treated silages (T2–T4). This indicates that the extent of putrefaction was higher in untreated silage due to low rate of decrease in pH during fermentation period that attributed to low WSC content of untreated pre-ensiled forage material. However, ammonia nitrogen content in both treated and untreated silages were within the acceptable standards for a well preserved silage (below 8%) as reported by Catchpoole and Henzell (1971). Acetic acid content was not significantly ($P>0.05$) different between treatments. The variation in acetic acid contents between treatments could be dependent of population size of heterofermentative lactic acid bacteria. Heterofermentative lactic acid bacteria produce 1 mole of lactic acid and one mole of acetic acid from one mole of glucose. Butyric acid content of untreated (T1) silage was significantly ($P<0.05$) higher than in treated silages (T2–T4). The reason for that could be due to slow rate of drop of pH in untreated forage that allowed larger population of Clostridia to grow than in treated forages. The value of butyric acid in untreated silage surpassed the standard (0–3 $gkg^{-1}DM$) for well preserved silage reported by Catchpoole and Henzell (1971), and Breirem and Saue (1973). This indicates that untreated guinea grass silage is prone to spoilage such that long preservation time could not be guaranteed.

Score grades:
Appearance:
1 = Poor – spoiled silage, dark brown in colour with mould growth
2 = Moderate – greenish with some mould growth
3 = Good – yellowish green to brown colour
4 = Very good – well pickled silage, yellowish green to light brown colour
Smell:
1 = Poor – foul smell associated with putrefaction
2 = Moderate – moderate pungent smell of ammonia
3 = Good – moderate pleasant smell
4 = Very good – pleasant ester aroma (typical silage smell)

Texture:
1 = Poor – slimy and watery
2 = Satisfactory – less slimy and wet
3 = Good – non slippery and slightly wet

The appearance score of untreated silage was significantly ($P<0.05$) lower than treated silages. Appearance of treated silage ranged from greenish with some moulds growth (T1) to yellowish green (T4). Results indicated that untreated silage had a poor smell followed by T2 silage which had a moderate pungent smell of ammonia. The rest treatments (T3 and T4) had a good smell characterized with moderate pleasant aroma. This observation entailed that increase in levels of sugar cane juice improved fermentation that could be reflected by improvement of fruit smell between treatments. The lowest score was observed in untreated silage probably due to poor fermentation characteristics that resulted into presence of moulds that caused slimy texture. Highest score was observed in T4 due to good fermentation quality attributed to good supply of fermentation substrates to lactic acid forming bacteria. However, it should be clear that organoleptic test is an arbitrary test due to variation between members of the test panel in terms of preference, sensitivity and skill. Nevertheless, this test could be useful to smallholder farmers because it does not involve sophisticated methods of assessment of silage quality and most of the farmers have no access to National laboratories due to economic barrier.

Results shown in Table 6 indicated that intake rate of untreated silage (T1) was significantly ($P<0.05$) lower than treated silages (T2, T3 and T4). The highest intake rate was observed in T3 probably due to low contents of acetic and butyric acids. Rogers et al. (1979) noted a negative relationship between organic acid and intake of silage. Furthermore, a negative correlation between intake and total organic acids and ammonia in silage has been reported by Thomas and Chamberlain (1983). However, they reported relatively higher voluntary intake in silage with higher proportion of lactic acid in the total acidity than silage with higher acetic acid in total acidity. In this study, lactic acid content of silage increased with increase in levels of sugar cane juice thus supports the argument. However, the intake rate of T4 silage was lower than T3 silage probably due to lower pH of T4 silage than T3. Low pH could result in alteration of normal rumen pH which consequently lowers the voluntary intake (Thomas et al., 1975). Therefore high proportion of lactic acid in total acidity is not a panacea to intake rate of silage. Optimum intake should be established before recommending the optimum level of inclusion of water-soluble carbohydrate additive.

Conclusion and Recommendation

This study aimed at investigating the effectiveness of sugar cane juice as an additive in guinea grass silage making. Results obtained in this study indicated that sugar cane juice improved quality of guinea grass silage. Sugar cane juice treated silages were of good aroma, low pH, low ammonia nitrogen and lactic acid dominated the organic acids produced.

From this study, the recommended optimum level of inclusion of sugar cane juice in guinea grass silages should be 10%, because at this level the silage produced was of good quality and had high rate of intake by crossbred dairy cows normally owned by smallholder dairy farmers of eastern coast of Tanzania.

Further investigations are recommended to establish the feeding value of the recommended guinea grass silage in comparison with Guatemala grass that dominates the feeding regime of highlands of eastern coast of Tanzania.

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