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Silage quality of cultural remains of pineapple pearl with different particle sizes and fermentation times

Qualidade da silagem de restos culturais de abacaxi pérola com diferentes tamanhos de partículas e tempos de fermentação

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ABSTRACT
The Triângulo Mineiro accounts for the largest production of pineapple in the State of Minas Gerais, the cultural rest is used as an alternative in animal nutrition. This study aimed to evaluate the quality of pineapple silage produced from pearl pineapple cultural remains. A completely randomized design was used in a 4 x 2 factorial scheme, with four fermentation times (30, 60, 90 and 120 days after silage) and two particle sizes (20 and 50 mm) and the contents of dry matter (DM), mineral matter (MM), organic matter (OM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEM), total digestible nutrients (TDN), total carbohydrates (TC), non-fibrous carbohydrates (CNF), and pH values. It was observed that the EE content increased by 42% when the silage remained stored for 60 days with particle sizes of 50 mm. There was a 7% increase in pH values at 90 days of fermentation in relation to the two particle sizes. In the silage composition of the pineapple crop remnant, particle size influenced crude protein, ether extract and pH.

Keywords: Pineapple, Alternative food, *Pineapple comosus L. Merril*, Bulky, Animal nutrition.

1 INTRODUCTION

Brazil is the third country with the world's largest pineapple production, with 1,637,126 tons, behind the Philippines and Costa Rica; being highlighted in the Brazilian production the states of Pará, Paraíba and Minas Gerais (CONAB, 2020; FAO, 2022). Therefore, the production of pineapple is of great economic interest, being cultivated in several regions of the country (SOUZA; COUTINHO; TORRES, 2010).

Minas Gerais stands out as the third largest producer of pineapple in the country, accounting for about 95% of the production, located in the Triângulo Mineiro region. In 2019, production reached 179.3 thousand tons in 6000 ha of planted area (SEAPA, 2020).

The increase in productivity and the improvement of fruit quality enables the production of more fruits per hectare, consequently a greater production of cultural remains. In Minas Gerais, pineapple cultivation stands out for its large production, reaching approximately 240 million fruits, in an estimated area of 7.7 thousand ha, which gives the state the position of the second largest national producer of the fruit (IBGE, 2017).

Another highlight is the planting of the main varieties for industry and table, respectively, the *pineapple Smooth Cayenne* (Hawaiian) and the pineapple Pearl (IBGE, 2017). Production is predominantly carried out by small farmers, in areas smaller than five hectares, on average, without irrigation, with few management practices and destined, in large part, to the Pearl variety (Souza *et al*., 2007; Rodrigues *et al*., 2010).

This is due to the cultivar produced, the Pearl pineapple that, by the characteristics of its plant provides greater planting density. Thus, these regions produce a large surplus of cultural remains. In this context, the fruit grower has sought new ways of using these remains, in order to minimize environmental impacts and prevent diseases in the crop.

The cultural remains of the pineapple plant are a source of forage of limited use in the places where it is grown, however, it presents potential for increased animal production (Marin *et al*., 2002). Food is the cost that most burdens livestock production. Thus, the use of alternative foods is increasingly employed in the current scenario. Increasing productivity requires greater use of food inputs to cover the critical periods of the annual forage production cycle and better expression of the genetic potential of cattle. The use of silage from pearl pineapple cultural remains becomes, therefore, a viable alternative aimed at reducing feed costs as well as a way to minimize environmental contamination, since the amount of vegetable waste produced is large (Santos *et al*., 2010).

In this context, the cultural remains of pineapple could serve as food in the form of silage, even contributing to lower the cost of feed for dairy cows. The silage process follows the same procedure for the corn plant, and trench or surface silos can be used. Silage has been used empirically, and studies are needed in order to enable its rational use as bulky, so that its use by the animal is more efficient, which basically depends on the knowledge of the bromatological composition and the digestibility of its nutrients. Thus, the present study aimed to evaluate the quality of pineapple silage produced from pearl pineapple cultural remains.

2 MATERIALS AND METHODS

The work was conducted in the Animal Nutrition Laboratory and in the Animal Unit of Digestive and Metabolic Studies and in the Dairy Cattle sector of the School of Agricultural and Veterinary Sciences, Jaboticabal Campus, State University of São Paulo (FCAV / UNESP), during the period from July 2012 to July 2013.

The cultural remains of pearl pineapple were chopped in a mobile fodder chop with precision hydraulic drive for cutting height (JF92 Z10), equipped with 10 knives for cutting according to the regulation. The material was ensiled in artificial silos consisting of double plastic bags with 50 cm x 80 cm in size and weight around 30 kg, being prepared 32 artificial silos, 16 with particle sizes of 20 mm and 16 with particle sizes of 50 mm; with scheduled opening times for every 30 days.

The artificial silos were kept indoors, free of moisture, covered with dark canvas, labeled with data such as fermentation days, particle sizes and opening dates; being placed in order of withdrawal for the collection of samples thus avoiding the incidence of light in the other silos. Every 30 days, 4 silos with particle sizes of 20 mm and another 4 with particles of 50 mm were opened until 120 days were completed. Samples of about 500g were taken from the central part of the silo, properly packed in a plastic bag, identified and frozen for later bromatological analysis.

At each collection period, about 50 g of fresh sample of each treatment was removed, which were sent to the laboratory of the University of the State of Minas Gerais, Frutal Campus, for the determination of pH, according to the methodology described by Silva and Queiroz (2009).

At the end of the 120-day period, the silage samples of Pearl pineapple cultural remains were thawed, and 300 g was used for bromatological analysis. The samples were pre-dried in an oven with forced air ventilation at 55°C for 72 hours and ground in a Willey mill in sieves with 1 mm mesh, stored and identified in plastic pots. Then, they were sent to the Animal Nutrition Laboratory of FCAV/UNESP of Jaboticabal for the performance of bromatological analyses, being determined the contents of dry matter, mineral matter, crude protein, ether extract according to AOAC (1990), neutral detergent fiber, acid detergent fiber according to Van Soest *et al*. (1991) and hemicellulose by difference between the contents of neutral detergent fiber and acid detergent fiber.

Total carbohydrate values were determined according to the methodology described by Sniffen et al. (1992), in which: CHOT = 100 - (CP + EE + ASH) and non-fibrous carbohydrates (CNF) were calculated according to Mertens (1997), where CNF = 100 - (NDF + CP + EE + ASH). The total digestible nutrients were obtained by the formula NDT = 87.84 - (0.7 x FDA), where FDA is acid detergent fiber (RODRIGUES, 2010).

For the bromatological analyses, a completely randomized design (DIC) was used in a 4 x 2 factorial scheme, with 4 fermentation times (30, 60, 90 and 120 days of fermentation) and 2 particle sizes (20 and 50 mm) with 4 replications. The means of the data were submitted to analysis of variance and compared through the Tukey test, at the level of 5% probability, using AgroEstat, v.1.1.0.701, (BARBOSA and MALDONADO Jr., 2011). The mathematical model used was:

$$\mathbf{Yijk} = \mathbf{m} + TFi + \mathbf{TPk} + (\mathbf{TF\ TP})\mathbf{ik} + eijk$$

Where:

m = Overall average

TFi = Effect the i-th fermentation time

TPk = Effect of k-th particle size

$(\mathbf{TF\ TP})_{ik}$ = Effect of the interaction between the i-th fermentation time and the k=th particle size.

eijk = Experimental error

3 RESULTS AND DISCUSSION

Table 1 shows the bromatological composition of the silage of pearl pineapple cultural remains with four fermentation times and two particle sizes.

It is noted that there was no interaction (P>0.05) between the contents of dry matter, organic matter, crude protein, neutral detergent fiber, acid detergent fiber, hemicellulose, mineral matter, total digestible nutrients, total carbohydrates and non-fibrous carbohydrates, except for the contents of ether extract (P<0.05) and pH (P<0.05), in relation to fermentation time and particle size.

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Pinto *et al*. (2005), Fagundes and Fagundes (2010), found similar results in the bromatological composition that they called pineapple hay, which is composed of plants crushed with forage machine and exposed to the sun for 3 days. The average of 5.95% of crude protein did not differ much from the results found in the 4 fermentation times, 2.54% of ether extract, a result 30% higher than that found at 30 days of fermentation time in the present experiment.

Table 1 - Mean values in Dry Matter (DM), in percentage, of Organic Matter (OM), Ether Extract (EE), Crude Protein (CP), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Hemicellulose (HEMI), Mineral Matter (MM), Total Digestible Nutrients (TDN), Total Carbohydrates (TC), Non-Fibrous Carbohydrates (CNF) and pH, of silage of pearl pineapple cultural remains. Frutal-MG. 2012/2013

	Treatments						**Treatments**					
	Fermentation times, days (T)				**Test F**	**DMS**	**Particle size, mm (TP)**		**Test F**	**DMS**	**F for interaction**	
	30	60	90	120			20	50			TxTP	CV
MS	18,91a	18,16a	18,40a	19,28a	1,89NS	1,43	18,8a	18,58a	0,36NS	0,76	2,69NS	5,57
WITH	94,69a	94,93a	94,93a	95,12a	0,34NS	1,37	94,60a	95,20a	2,97NS	0,72	0,32NS	1,04
ES	1,94a	2,33a	2,25a	2,06a	1,96NS	0,50	2,10a	2,19a	0,30NS	0,26	4,16*	17,04
PB	5,27a	5,43a	5,51a	5,40a	0,73NS	0,46	5,53a	5,28b	4,30*	0,24	0,82NS	6,23
FDN	52,46a	53,49a	49,91a	54,39a	2,20NS	5,09	52,96a	52,95a	0,37NS	2,69	1,45NS	7,02
FDA	20,02a	31,48a	30,40a	31,77a	2,90NS	2,85	30,81a	30,52a	0,16NS	1,51	1,03NS	6,75
HEMI	23,44a	22,01a	19,50a	22,62a	1,29NS	5,83	22,14a	21,65a	0,11NS	3,08	0,59NS	19,29
MM	5,37a	5,06a	5,07a	4,88a	0,34NS	1,37	5,40a	4,79a	2,97NS	0,72	0,32NS	19,48
pH	3,81b	3,87b	4,17a	3,87b	17,66**	0,14	3,94a	3,92a	0,31NS	0,08	3,39*	2,75
NDT+	67,53a	65,80a	66,55a	65,60a	2,89NS	1,99	66,27a	66,47a	0,16NS	1,06	1,03NS	2,18
CHOT++	87,42a	87,17a	87,16a	87,65a	0,34NS	1,57	86,96a	87,74a	3,70NS	0,83	0,72NS	1,30
CNE+++	34,95a	33,68a	37,25a	33,26a	2,06NS	4,87	34,00a	35,56a	1,55NS	2,58	1,84NS	10,16

Means followed by the same letter on the line do not differ from each other by Tukey's test (P>0.05). NS, *, **: not significant; significant at 5 and 1% probability by the Tukey test, respectively.
CV (%) = Coefficient of variation. DMS (%) = Minimum significant difference.
+ Averages calculated according to RODRIGUES, 2010, where NDT = 87.84 - (0.7 x FDA), in % in DM
++ Means calculated according to McDOWELL et al. (1974), where CHOT = 100 - (CP + EE + MM), in % in DM
+++ Averages calculated according to Mertens (1997), where CNF = 100 – (PB +EE + ASH), in % in DM

Acidity is an important factor in the conservation of silage, as it acts by inhibiting or controlling the development of harmful microorganisms, such as bacteria of the genus Clostridium. The pH value indicates whether the fermentation was satisfactory, and its determination was used in the evaluation of silage quality (Pereira *et al*., 2007).

Comparing the contents of neutral detergent fiber and acid detergent fiber, averages of 52.69% and 29.16%, respectively, with the contents found for corn silage by Zanine (2007), averages of 66.11% and 32.96%, respectively, the silage of pearl pineapple crop remains showed a decrease of 13% in the acid detergent fiber content.

Muller (1978), cited by Fagundes (2010), states that the contents of total digestible nutrients of tropical grasses and legumes present values around 55%, while the contents found in this experiment were, on average, around 66%, which represents an increase of 20%.

The unfolding of the interaction between fermentation time and particle sizes for the ether extract contents (Table 2) showed that the average ether extract contents were higher when the silage remained longer in fermentation, with the greatest difference of 1.91 and 2.44% of ether extract (P<0.01). This difference corresponds to an increase of 27.74% of the time of 90 in relation to 60 days of fermentation with particle size of 20 mm.

Table 2. Unfolding of the interaction between fermentation times and particle size for the ether silage extract of pearl pineapple cultural remains.

TP (mm)	**T (days)**				**Test F**	**DMS (5%)**
	30	**60**	**90**	**120**		
20	1,95aA	1.91aB	2,44aA	2,12aA	1,74NS	0,71
50	1,93bA	2,75aA	2.06abA	2,01bA	4,32*	
F-test	0,01NS	10,52**	2,15NS	0,19NS		
DMS (5%)	**0,53**					

Averages followed by different letters in columns (uppercase) and rows (lowercase) differ from each other by the Tukey test.
NS = not significant; *(P<0.05); **(P<0.01); DMS = minimum significant difference; T = Fermentation time; TP = Particle sizes.

From the point of view of the ether extract content it is interesting that the fermentation period is 90 days, this when the pineapple cultural remains are ensiled with particle sizes of 20 mm. If the chopping is done allowing particle sizes of 50 mm, it is interesting to keep the silo closed until the fermentation period of 60, since the increase in the content of ether extract from 30 to 60 days of fermentation was 42%. Considering the values of ether extract at 30 days of fermentation, regardless of particle size, if there is a need to open the silo, the silage will have lower levels of ether extract.

By unfolding the interaction between fermentation times and particle size for pH, it was verified that there was no difference (P>0.05) at 90 days of fermentation in relation to particle sizes of 20 and 50 mm. The pH presented values of 8.04% and 6.68% higher in relation to the values of 30 and 60 days of fermentation, returning to the same level with 120 days of fermentation (Table 3).

Table 3. Unfolding of the interaction between fermentation time and particle sizes for pH, from the silage of pearl pineapple cultural remains.

TP (mm)	**T (days)**				**Test F**	**DMS (5%)**
	30	**60**	**90**	**120**		
20	3,73bB	3.88aB	4,19aA	3.96aB	12,35**	0,21
50	3,89bA	3,85aB	4,15aA	3,78bB	8,70**	
F-test	4,64*	0,18NS	0,27NS	5,37*		
DMS (5%)	**0,15**					

Possenti *et al*. (2005) studying the bromatological and fermentative parameters of corn and sunflower silages, observed that a stable pH is not obtained in silages, which is due to the deficiency of soluble carbohydrates or due to excessive moisture of the material, which can be noticed in the silage of pineapple cultural remains, due to the high moisture content. The appropriate pH value to promote an efficient conservation of ensiled forage depends on the moisture content of the silage (Cunha *et al*., 2009).

Tomich *et al*. (2004), reported that pH values between 3.8 and 4.2 are considered adequate for well-preserved silages, because in this range there is the restriction of proteolytic enzymes of the plant and of enterobacteria and clostrids.

In the present experiment, the pH of the silage of pineapple cultural remains varied in the different fermentation times between 3.73 and 4.19. The lowest average obtained at 30 days of fermentation, with a particle size of 20 mm, approaches the ideal range of 3.8 reported by Tomich *et al*. (2004) and Cunha *et al*. (2009), but this value cannot be considered ideal, recommending the wait for 60 days to open the silo. Similar values were also found by Cunha *et al*. (2009) when comparing silages of different proportions of industrial waste of pineapple and maniçoba and Pereira *et al*. (2007) in evaluation of corn silages.

4 CONCLUSIONS

In the silage composition of the pineapple cultural remainder, particle size and fermentation time influenced crude protein, ether extract and pH. The crude protein and pH in particle size between 20 to 50 mm at 90 days of fermentation and for the ether extract the highest value was in the size of 50 mm at 60 days of fermentation of the silage of pearl pineapple cultural remains.

As the particle size and fermentation time practically did not influence the composition of the silage, the chopping of the material can be done according to the availability of the type of siladeira, in smaller particle size, 20 mm or larger, 50 mm.

Further research is suggested in order to verify the performance of dairy cows fed with pineapple crop silage, including economic analysis, pointing out its viability in relation to the cost of the kilogram of milk produced and profitability.

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