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Changes in the Concentration of Short Chain Fatty Acids, PH, Dry Matter and Minerals Duringthe Process of Ensiling a Mixture of Swine Manure and Choped Sugar Cane

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Abstract: With the objective of studying PH changes, acetic, propyonic, butyric and lactic acids concentrations together with dry matter and mineral content during the process of ensiling mixtures of porcine fresh manure with choped sugar cane. A series of microsilos was made following a factorial design with 60 and 70% porcine faeces and 30 and 40% chopped sugar cane, respectively, samples were taken at 0, 30. 45 and 60 days with 5 repetitions each. The differences in PH and concentration of dry matter, short chain fatty acids and minerals were used to determine the quality of ensiling. No change was observed in the concentration of dry matter in all treatments ($p>0.05$), PH tended to be more acid as ensiling time progressed. Acidity was correlated to the concentration of short chain fatty acids ($r=0.99$). The production of Lactic acid predominated and butyric acid was used as an indicator of ensiling quality. The concentration of Acetic, propyonic, lactic and butyric acids present were with in the range of what is considered a good quality silage. The concentration of minerals was related to the % of porcine manure used in the silo. These results shows that monitoring the contents of fatty acids, PH, dry matter and minerals can be useful when this type of silage is intended for ruminants feed.

Key words: Silage, porcine faeces, sugar cane, fatty acids, minerals

INTRODUCTION

Due to the high content of organic an inorganic substances present in swine manure, it is possible to use it as an energy source for the production of fuel such as methane and for soil fertilizer[1-4].

The use of porcine manure as an ingredient of silage is well known, because of high concentrations of minerals and proteins that can be an important source of energy for ruminant feeding[5-8]. When porcine manure is included in the composition of silage, their presence improves significantly the organoleptic characteristics of the silage and increases the amount of soluble carbohydrates when lactic fermentation is carried out, favouring smell and taste for further consumption by ruminants[9-13]. The objective of ensiling manure is to avoid the loss of nutrients of the ingredients[14,15]. Acetic, propionic, butyric and lactic acid fermentations are desired in the process of ensiling; because they exert an antiseptic action in the gastrointestinal tract of the ruminant, improving its function[3,16,7,10,11,14,15].

As mentioned before, ensiling porcine faeces permits its use for animal feeding, however, more information is desired related to the concentration of short chain fatty acids, dry matter, minerals together with PH changes during the fermentation process. Thus the objective of this work was to study changes in PH, dry matter, mineral content and short chain fatty acids when mixing porcine faeces (solid fraction) with chopped sugar cane with the purpose of producing silage for ruminant feed.

MATERIALS AND METHODS

Porcine fresh manure was obtained from a commercial pig farm collected from the maternity area where sows were fed (Purina) maternal sow pellets with water ad libitum; sugar cane was obtained from a sugar factory (Ingenio morelos, Hidalgo, Mexico), samples were taken during the normal sugar cane harvest. The sugar canes were taken at random and chopped with an agricultural ensiling chopper.

Different mixtures were studied in this experiment the experiment followed a factorial arrangement in which two percentages of faeces (60 and 70%) were mixed with two percentages of chopped sugar cane (30 and 40%). Samples were obtained from these mixtures

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at four different times of ensiling, (0, 30, 45 and 60 days).

Samples on day zero were taken immediately after mixing the ingredients and frozen for further analysis. The resulting mixtures were hand compacted and deposited in plastic jars and tagged according to its treatment. To insure proper fermentation they were hermetically closed and sealed in order to create an anaerobic environment.

At the end of each period of study (30, 45 and 60 days) jars were opened and a sample of 200g was taken from the central part of each micro silo and PH and dry matter content was measured. The 200 g samples taken from of each micro silo were hermetically sealed in plastic bags, tagged and kept frozen until further analysis.

The content of acetic, propionic, butiric and lactic acids were determined by gas chromatograPHy[17-19].

The concentration of minerals was determined after incineration and reconstitution of the sample to a known volume, there after; readings were carried out using absorption or emission spectrometry, in accordance with the needed element, following instrument specifications for each element. PHosphorus was measured using a colorimetric method[20-23].

Results were subjected to a statistical variance analysis. A Turkey test of media comparison was carried out when significant differences between treatments were detected. For the variables with amounts expressed on percentage the transformation was done using the square root or the arccosine so that the results fulfilled the requirement of adjusting to a normal distribution; a simple correlation analysis between variables was also done [24,23].

RESULTS AND DISCUSSION

Variations of PH in sugar cane and porcine manure silage are shown on Table 2. The initial acidity of the ingredients used for this experiment was, 3.9 and 5.2 for sugar cane and porcine manure, respectively. During the time of study the acidity of the mixture (silage) showed a tendency to increase with time ($p<0.05$). It was observed that when the amount of manure, PH increased ($p<0.05$).

Before ensiling the PH of mixtures with 60 and 70% of porcine faeces was similar ($p<0.05$), but after 30 days of treatment they were significantly acidified ($p<0.05$).

The effect of treatment on dry matter percentage can also be observed on Table 1. Before ensiling, the concentration of dry matter in chopped sugar cane (32.12%) was 7% greater than the one of porcine faeces (25.92%), sixty days after ensiling the percentage of dry matter of the mixture 60/40 was (31.33%). The increase in dry matter was slightly higher ($p<0.05$) associated to time of ensiling or percentage of manure.

The concentration of acetic, propyonic, butyric and lactic acids showed significant differences ($p<0.05$) due to differences in the porcine manure/chopped sugar cane proportions, the concentration of lactic acid was higher in the mixture that had 70% of faeces (2.58%) as it was related to the amount of sugar cane (2.4%). The concentration of acetic acid showed increases associated to time and effect ($p<0.05$; it was observed that at 0 days it was on the order o 0.195% and at 60 days increased to 0.413%, this means an increase of 0.218%.

The amount of propyonyc acid increased in a similar pattern as acetic acid did, this increase went from 0.079% at 0 days up to 0.081% at 60 days; this rise ($p<0.05$%) was not significant.

The butyric acid concentration before ensiling was of 0.046% and decreased ($p<0.01$) after 30 and 45 days to 0.037 and 0.036%, respectively. After this decrease, it presented a rise (0.04%) with no significant statistical difference ($p<0.05$) when compared to the other two ensiling times. With 70% manure the lactic acid had an average of 1.384% that was significantly different ($p<0.05$) on each one of the ensiling periods.

Variations on mineral elements were as follows: calcium concentration was 3.047%, sodium 823.9 ppm and magnesium 926.1 ppm on the silage with 70% porcine manure. Calcium had a variable behaviour ($P<0.05$) during the ensiling time (0 days=2.693, 30 days=3.208, 45 days=2.482 and 60 days=3.322%), in the silo with 70% manure, average Ca concentration was 3.05%; in silo with 60% manure thereafter it decreased to 2.80%. Phosphorus had a similar behaviour, but the concentration increased slightly when comparing faeces proportions ($p>0.05$). The one with 60% had a P content of 1.077% and with 70% faeces it had 1.061%. The concentration of Phosphorus averaged 1.054% during all the ensiling process, observing only a slight increase ($p>0.05$), at 30 days of ensiling increasing up to 1.113%. Magnesium had non significant increases ($p>0.05$) (day 0=841.5 ppm; 30 days=810.0 ppm; 45 days:=907.2 ppm and 60 days= 927.2 ppm). Sodium had a series of increases and decreases at the registered sampling times, during the ensiling process ($p<0.05$), initially it was 864.3 ppm, which decreased at 30 and 45 days, reaching an average concentration of 599.6 ppm and then it rises to 997.0 ppm at 60 days of ensiling ($p<0.05$)

Potassium had an increase of 11.18% ($p>0.05$) between 0 (1943.3 ppm) and 60 days (2187.7 ppm), (Table 2) which was associated to the amount of added sugar cane ($p<0.05$).

The concentrations of other minerals after adding 60% of the pork manure were as follows: Mn (44.69 ppm), Cr (5.52 ppm), Fe (417.90) and Cu (13.39 ppm) and after

Table 1: The concentration of fatty acids and dry matter of porcine manure and chopped sugar cane mixtures after ensiling for 0, 30, 45 and 60 days (means ± standard deviation)

60% procine manure 40% chopped sugar cane

Days	Acetic acid (%)	Lactic acid (%)	propionic acid (%)	butyric acid	Dry matter (%)(%)
0	0.195	0.045	0.079	0.046	29.7
	±0.043	±0.003	±0.004	±0.005	±2.5
30	0.390	2.553	0.080	0.037	30.5
	±o.oo39	±0.919	±0.009	±0.009	±3.0
45	0.418	3.229	0.080	0.036	29.9
	±0.004	±0.803	±0.008	±0.007	±2.9
60	0.413	4.153	0.081	0.0.40	31.33
	±0.004	±0.905	±0.010	±0.009	±2.0

70% procine manure 30% chopped sugar cane

Days	Acetic acid (%)	Lactic acid (%)	propionic acid (%)	butyric acid	Dry matter (%)(%)
0	0.205	0.030	0.075	0.048	29.90
	±0-045	±0.009	±0.008	±0.007	±2.0
30	0.359	1.384	0.078	0.039	29.90
	±0.0040	±0.513	±0.0069	±0.0042	±2.9
45	0.470	1.394	0.090	0.039	31.0
	±0.053	±0.32	±0.019	±0.009	±3.0
60	0.475	1.399	0.089	0.039	32.50
	±0.049	±0.040	±0.009	±0.009	±2.8

Table 2: The PH and mineral content of porcine manure and chopped sugar cane mixtures after ensiling for 0, 30, 45 and 60 days (means ± Standard Deviation)

60% porcine manure 40% chopped sugar cane

Days	Ca (%)	Na ppm	Mg ppm	Fe ppm	Cu. p	K ppm	P ppm	Mn ppm	Cr ppm	Zn ppm	PH ppm
0	2.69	823.9	926.1	437.7	13.55	1843.33	1.07	44.69	3.49	45.9	4.8
	±0.31	±12.8	±23.2	±16.1	±1.30	±75.3	±0.06	±2.3	±0.41	±1.8	±0.9
30	3.20	599.6	931.3	421.13	13.91	1847.3	1.06	42.00	3.5	44.9	3.6
	±0.8	±18.3	±30.2	±19.4	±1.0	±53.7	±0.10	±3.0	±0.39	±2.0	±0.8
45	2.48	599.0	915.7	485.14	14.10	1840.3	1.05	43.0	3.48	45.3	3.5
	±0.5	±21.0	±39.0	±15.1	±1.2	±49.2	±0.09	±2.8	±0.45	±1.9	±0.8
60	3.32	997.0	926-1	499.14	15.08	1900.7	1.054	44.0	3.5	45.00	3.5
	±0.6	±19.0	±28.3	±19.0	±1.5	±79.0	±0.09	±2.1	±0.35	±2.0	±0.7

70% porcine manure 30% chopped sugar cane

Days	Ca (%)	Na ppm	Mg ppm	Fe ppm	Cu. p	K ppm	P ppm	Mn ppm	Cr ppm	Zn ppm	PH ppm
0	3.047	864.3	841.5	521.3	11.56	1943.0	1.067	48.67	3.69	48.5	4.79
	±0.40	±15.0	±39.9	±17.0	±0.9	±69.0	±0.10	±1.9	±0.51	±1.2	±0.89
30	3.06	599.0	810.0	520-01	14.00	1900.0	1.113	46.69	3.60	48.0	3.65
	±0.38	±20.0	±29.0	±23.0	±1.0	±57.0	±0.09	±1.5	±0.49	±1.3	±0.80
45	3.05	599.6	907.2	499.0	14.01	1999.0	1.061	47.81	3.50	47.90	3.49
	±0.39	±18.0	±25.1	±30.0	±0.99	±49.0	±0.10	±1.60	±0.39	±1.6	±0.79
60	3.05	997-0	927.2	518.0	13.99	2187.7	1.054	48.3	3.59	68-0	3.45
	±0.40	±17.0	±23.0	±19.0	±0.92	±39.0	±0.13	±1.1	±0.48	±1.7	±0.79

adding 70% values were as follows: Mn (48.67 ppm), Cr (9.69 ppm), Fe (521.30 ppm) and Cu (11.56 ppm).

The ensiling period didn't modify significantly the Fe and Cu concentrations ($p>0.05$), at 0 days concentrations were: Fe (437.70 ppm) and Cu (13.55 ppm) and at 60 days were (499 Fe ppm) and (15.08 Cu ppm) while Mg, Cr and Zn had an increase related to the content of manure ($p<0.05$). As time went on Mn values were: 2.32 ppm; Cr: 3.49 ppm and Zn: 45.9 ppm.

The findings reported in this work are similar to other[14,15,7]. There is agreement in relation to the optimum concentration of dry matter and we also agree that when porcine manure is used, the concentration should fall on the range of 30 and 40%.

When the concentration of dry matter is above 60% the ensiling process is more difficult to develop and there is a decrease in the production of fatty acids. And when humidity was below 28% undesired fermentations developed.

The amount of dry matter in porcine manure silage is variable due to the amount of water present when collected from the farm. Furthermore, it should be considered that the chemical composition will be related to the proportion of the different components of the mixture and the digestibility of concentrates used. And it will be also influenced by the dry matter content of the ingredients during the ensiling process.

McCullough[25] indicates that when using chopped corn for ensiling there is a high concentration of acetic

acid, higher than butyric acid. But their concentration does not go higher than the concentration of lactic acid, showing that there is an adequate transformation of soluble carbohydrates during the first 3-5 days of the ensiling.

Estrada[10] found that the concentration of acetic acid was lower that 1.5% when low concentrations of manure were used for silage.

According to McCullough[25] when chopped corn silage presents a higher concentration of acetic acid, it means that there is an adequate transformation of soluble carbohydrates during the first stages of lactic fermentation, such as that found during the first 3 to 5 days of ensiling. Estrada[10] reported concentration of acetic acid lower that 1.5% on manure silage, the latter associated with low quantities of manure in the silage.

When the concentration of butyric acid in corn silage is higher than 1% the resulting silage will be considered of poor quality. And when the concentration of butyric acid is lower that 0.5% consumption in ruminants is decreased[10,7].

The concentration of lactic acid reported in this work was lower that that reported by Iñiguez[14,15] when ensiling porcine manure and yucca tubercles, in relation to this report, McCullough[25] states that for such purpose the amount of porcine manure should be between 0.89 and 3.5%.

When porcine manure was obtained from a pre fattening sow farm in Cuba the concentration of lactic acid was reported to be between 10.6 and 4.28%[5], similar to the ones here reported.

The variations in the compositions of this type of silage so far mentioned, show that the composition of porcine manure should be considered; before using it for silage making in order to avoid nutritional misbalances.

Calcium concentrations of the silage here studied were considered sufficient for the production and maintenance needs of: pigs (0.6-0.9%), bovine (0.24-0.70%), ovine and goats (0.21-0.52%)[7,8,26].

The excess of phosphorus found in this work is not deleterious, however it might cause misbalances on minerals highly related to P, such as Ca, Mg, Mn and K[20].

Toledo[7] found that the concentration of Mg were lower to the ones here reported and this might be because Mg is present on the liquid fraction of manure separated from the solids, however this observation needs further verification.

Campabadal[20] reported sodium values much higher to the ones found on this experiment. It is presumed that the mayor part of it is found in the liquids separated from the faeces, which has to be analyzed mostly on those places where such waste waters are used to irrigate soils, because it can cause a decrease of fertility due to its accumulation.

Kornegay *et al.*[27] reported that the concentration of K in porcine manure shows ranges between 13000-18000 ppm. However; the amounts of potassium found in this study are insufficient to satisfy the needs of productive animals, because they oscillate between 50,000-100,000 ppm. On meat producing steers the maximum acceptable amounts of sodium that do not cause toxicity is around 30,000 ppm, therefore to produce toxicity with the use of these silage is very difficult, since potassium and sodium are provided in excess they are promptly eliminated through the urinary tract[28].

Toledo[7] found much higher concentrations of mg as compared with our findings, exceeding the needs for maintenance and production on ovine, goats and bovine[29-31]. On this species 1000 Mg ppm are recommended as the maximum allowable level, however higher concentrations interferes with the absorption and metabolism of Fe. The allowance of Zn for milk producing bovines in the feed ratio is 40 ppm; for ovines 20-33 ppm and up to a maximum of 500 ppm for bovines and 750 ppm for ovines. The concentration of Zn in this study was high and this concentration limits the availability of Ca and Fe (NRC). Toledo[7] found lower values in similar silage, but the values found by other authors[15,27,30] on porcine manure alone, were higher to the ones here reported.

Trivalent Cr is an important mineral because interacts with the hydrolysis of glucose, however, information related to toxic concentrations of this element for cattle is lacking[15,27,30]. Cu is considered toxic for sheep and cattle when it exceeds 50 and 200 ppm, respectively, although no more than 20% of the ingested Cr is absorbed[23,30].

It was concluded that the differences in the mineral concentrations mentioned are related to different factors, specially the variations on the chemical composition of the ingredients that integrated the micro silos. Therefore it is of great value to randomly carry out studies such as the ones here reported to obtain more information related to silages made with porcine manure.

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