Chemical characteristics of silages of mango (*Mangifera indica* L.) by-products for animal feeding

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The chemical characteristics of six silages based on agro-industrial residues and mango residues were assessed with the addition of two levels of maize stubble, molasses and agricultural urea. A factorial scheme 2 x 6 x 6 was applied with two replicates per treatment. The factors assessed were the season (June-August 2009), the silages time (0, 7, 14, 21, 42 and 84 d) and six types of silages. Three of the micro-silos were made with mature fruit discarded for human consumption, and other three with mango industrial by-products (mainly the peel and seed). All the silages had maize (10 and 20 %), with or without molasses and urea. Any interaction was significant for the concentration of NDF and CP of the micro-silos. However, the OM, ADF and lignin were influenced by the interaction additive x day and season x additive x day. The use of silages with discarded mature mangos, as well as those elaborated with industrial by-products of mango for animal feeding, especially ruminants, is suggested. Adding maize stubble between 10 and 20 %, apart from agricultural urea and sugarcane molasses, with 3 and 2 % of inclusion in dry basis is also recommended. These silages should be assessed in performance tests applied to ruminants.

Key words: *silage, mango waste, chemical composition*

The use of agro-industrial by-products in animal feeding is a viable alternative in the tropics. It has been applied for decades to increase the quality of the final product, reduce the production costs and use properly those potentially polluting materials (Olivera *et al*. 2006 and Vieira *et al*. 2008). The production of tropical fruits, including mango and its wastes, together with the necessity of a sustainable alternative for using its by-products and reducing its polluting effect, are conditions for its use as silage. In the case of nayarita mango, the harvest is conducted in three months, between June and August (Pérez *et al*. 2006, 2009), increasing, in a short period of time, the amount of waste, both of non-exportable products and residues of the processing industry. The improper disposition of these by-products implies, logically, the environment deterioration. In three months, in 2005, Nayarit reported a harvest of more than 200.000 t of mango commercialized. (SAGARPA 2005). On this respect, it has been proved that the use of mango for juice and pulp generates an amount of residues corresponding with at about 28-43 % of the total of fruits (Ferrer 1987).

The silage technique has proved to be a proper alternative for preserving the agroindustrial by-products of tropical fruits, as those of citrus (Llano *et al*. 2008) and pineapple (Herrera *et al*. 2009). In the specific case of mango residues, there are antecedents in Mexico (Scotillo 1984 and Aguilera *et al*. 1997) and recent studies referring (Vinent 2003, Filho *et al*. 2006, 2010, Sá *et al*. 2007, Vieira *et al*. 2008 and Rego *et al*. 2010) the use of mango and other mature fruits by-products in animal feeding.

The objective of this study was to assess the chemical characteristics of six silages based on agroindustrial and mango fruit by-products with the addition of two levels of maize stubble, molasses and agricultural urea.

Materials and Methods

This study was carried out in the facilities of the Academic Unit of Agriculture of the Autonomous University of Nayarit. Previous studies of Guzmán (2010) report details about the location of this unit. The weather is semi-warm or humid sub-tropical, according to the classifications of Kopper. The pluvial status surpasses 1 300 mm annually, and the month of maximum rainfall is July, with 370-280 mm, while that of less incidence is May, with 30 mm. The mean annual temperature varies from 20 to 29 ºC. The warmest months are between June and September, with mean temperature of 23-24ºC, while the coldest months (16-17 ºC) correspond to December and January (García 1983). Tepic is at about 1 000 m a.s.l.

A factorial scheme 2 x 6 x 6 was applied, with two replicates per treatment. Season (June and August 2009), silage time (0, 7, 14, 21, 42 and 84 d) and six types of silages were assessed and their compositions are described in table 1. The composition of the silages followed the main suggestions of Aguilera *et al*. (1997).

Three micro-silos were prepared with waste mature mangos, not used in human feeding and without the requisites established by the enterprises for their industrialization. Other three were

Table 1. Characteristics of the materials when closing the micro-silos (day 0 of ensilage)

Indicator	Whole fruit, %			Industrial by-product, %		
	75	80	85	75	80	85
	2	5	1	4	6	3
Composition, % in fresh basi						
Whole fruit	75.0	80.0	85.0	-	-	-
Residue	-	-	-	75.0	80.0	85.0
Maize stubble	20.0	20.0	10.0	20.0	20.0	10.0
Urea	2.0	-	2.0	2.0	-	2.0
Molasses	3.0	-	3.0	3.0	-	3.0
Analysis, % in dry basis						
DM	40.4	40.3	34.5	42.7	37.1	43.2
NDF	55.9	63.8	52.5	58.1	65.4	53.5
ADF	33.1	39.0	30.3	31.3	34.3	30.7
Hemicellulose	22.2	24.7	22.2	26.7	31.1	22.7
Cellulose	23.8	27.2	22.1	22.6	25.2	21.5
Lignin	9.3	11.7	8.2	8.6	9.0	9.2
Nx6.25	12.7	5.1	15.0	9.1	4.3	11.9

elaborated with the industrial by-product, mainly composed of peel and seed, coming from a local plant processer of tropical fruits. In both cases, the variety of Tommy Atkins was used.

The micro-silos preparation was conducted with two types of mango residues of the variety cultivated, from the beginning and ending of the harvest season, between June and August 2009. The first type of residue was waste fruit, which appearance and consistence was not suitable for human consumption and did not achieve the demands of the enterprises for their industrialization. This residue was obtained from one of these processing plants. The second was created after the industrialization of this fruit, mainly composed of peel and seed. Stubble maize without grains, with local origin, was used as well as sugarcane molasses and agricultural urea.

The industrial by-products of mangos, as well as the rejected fruits, were milled in mix miller with blades and hammer, in order to obtain more homogeneous samples and facilitate the silage process. The maize stubble was cut equally, with a sieve of 2.5 cm, to obtain a particle size with the same dimensions. The micro-silos were manually prepared, at lab scale, with four repetitions per each preservation time in the six treatments. The material for the silage was introduced in polyethylene bags at a rate of 5 kg. The bags were compacted and closed hermetically with a vacuum pump to guarantee their preservation. The micro-silos were stored under roof and the environmental temperature was daily recorded at 9:00 a.m. and 3:00 p.m. They were opened at 0, 7, 14, 21, 42 and 84 d after silage.

The material was analyzed for DM content, ash and CP (N x 6.25), according to AOAC (1990). The levels of NDF, ADF and lignin were measured following van Soest and Robertson (1975). It was considered that the OM concentration was equal to the difference 100 – ash percent. However, the hemicellulose was the result of the subtraction (NDF – ADF), as well as the cellulose (ADF – lignin), both expressed in percent (van Soest and Robertson 1975). All the determinations were made by duplicate.

The means were contrasted by the analysis of variance technique, according to the recommendations of Steel *et al*. (1997). Where significant differences ($P < 0.05$) were found, they were compared with the Tukey test. The statistical software SAS (2003) for computers was used in all the analyses.

Results

During the storing process, the mean environmental temperature during the experiment was of 27.5 and 38.5 ºC, at 9:00 a.m. and 3:00 p.m. respectively. When opening the micro-silos, the presence of alcohol or any symptom of putrefaction was never found. All of them had a nice smell and it was never necessary to remove the superficial cover due to the presence of fungi.

The result of the interactions studied for the chemical indexes is shown in table 2. The interaction season x additives was not significant. No significant effect was found in the interactions studied for the concentration of NDF and CP. The preservation time seemed to be a main effect determining the significant interactions ($P< 0.05$) found.

Table 2. Interactions in chemical indexes of ensilaged mango products

Interactions	Ash	OM	NDF	ADF	Lig	CP
Season x additives	NS	NS	NS	NS	NS	NS
Season x days[1]	*	*	NS	NS	NS	NS
Additives x days	*	*	NS	*	*	NS
Season x additives x days	*	*	NS	*	*	NS

1 preservation time of the micro-silos
*P < 0.05

The season effect on the chemical characteristics of the micro-silos is presented in table 3. The OM content kept invariable during the two months assessed. The NDF and ADF concentration, as well as that of lignin, was significantly (P < 0.05) higher in August than in June. The hemicellulose content decreased (P < 0.05), and that of the cellulose increased (P < 0.05) concomitantly. The CP concentration of the micro-silos was lower (P < 0.05) at the end of the season than at the beginning.

The preservation time effect on the chemical characteristics of the silages is shown in table 4. There was no significant effect of the preervation days on the concentration of the different chemical indexes assessed, except on the NDF content that was lower (P < 0.05) at the beginning and end of the silage process, in respect to the other times measured.

The treatment effect on the chemical composition of the micro-silos is shown in table 5. The treatments without molasses and agricultural urea showed lower levels of ash and CP, and higher concentration of OM, NDF and ADF (P < 0.05). On the other hand, in other fiber fractions such as ADF, hemicellulose and lignin, the additives added to the silage products did not influence.

Table 3. Chemical characteristics in mango nayarita ensilages. Season effect (per cent in dry basis)

Indicator	June	August	SE ±
DM	33.15	29.23	0.75*
Ash	1.92	3.07	0.09
OM	98.07	96.92	0.09
NDF	64.48	69.12	0.77*
ADF	39.05	50.57	0.75*
Lignin	10.67	19.79	0.35*
Hemicellulose	25.42	18.55	0.69*
Cellulose	28.38	30.98	0.60*
CP, N x 6.25	11.86	9.29	0.73*

N = 72
n* P<0.05

Table 4. Chemical characteristics of ensilages of nayarita mango. Effect of the preservation time (per cent in dry basis)

Indicator	Days of ensilage						SE±
	0	7	14	21	42	84	
DM	34.60[a]	30.50[b]	30.54[b]	29.81[b]	30.93[ab]	30.77[ab]	3.71*
Ash	2.38	2.45	2.50	2.35	2.68	2.61	0.41
OM	97.61	97.54	97.49	97.64	97.31	97.38	0.41
NDF	65.65[c]	69.61[a]	68.70[a]	68.24[ab]	67.69[ab]	64.52[bc]	2.34*
ADF	40.79	45.16	46.48	45.97	46.71	43.76	3.57
Lignin	14.02	15.42	16.04	15.77	15.82	14.30	2.52
Hemicellulose	21.86	24.45	22.21	22.27	20.37	20.75	2.65
Cellulose	26.76[b]	29.73[a]	30.44[a]	30.19[a]	30.88[a]	29.45[a]	2.04*
CP	9.06	10.67	10.90	10.67	10.62	11.36	2.34

[abc] Means in the same row without common letter differ significantly (P < 0.05) among them
N = 24
*P < 0.05

Table 5. Chemical characteristics of ensilages of nayarita mango. Effect of the type of additive (per cent in dry basis)

Indicator	Whole fruit, %			Industrial by-product, %			SE±
	75	80[1]	85	75	80[1]	85	
DM	32.06[b]	27.03[c]	26.62[c]	35.41[a]	32.98[ab]	33.05[ab]	0.18*
Ash	3.10[a]	2.21[b]	2.38[b]	2.75[ab]	2.27[b]	2.75[ab]	0.38*
OM	96.89[b]	97.78[a]	97.61[a]	97.24[ab]	97.72[a]	97.24[ab]	0.38*
NDF	66.84[abc]	70.66[a]	64.42[c]	66.03[bc]	69.47[ab]	63.39[c]	2.30*
ADF	45.45	47.78	44.28	43.60	45.73	42.03	3.60
Lignin	14.44	15.21	15.46	15.69	14.80	15.79	2.54
Hemicellulose	21.38	22.88	20.13	22.43	23.73	21.36	2.65
Cellulose	31.01[ab]	32.56[a]	28.81[bc]	27.91[cd]	30.93[ab]	30.93[ab]	1.60*
CP	12.87[a]	5.42[c]	14.92[a]	11.86[b]	4.83[c]	13.39[ab]	1.25*

[abcd] Means without common letter in the same row differ significantly ($P < 0.05$) among them

[1] No urea and sugar cane molasses (see table 1)

N = 24

*$P < 0.05$

Discussion

Season effect. Light differences were found between the beginning and end of the mango processing season, specifically in the characteristics of the ensilaged materials. The DM concentration of the silages was lower in August than in June but, in both cases, the mean values were within the recommended range (25-35 %) to characterize a proper-quality ensilage (McCullough 1975). In this sense, McDonald *et al*. (1981) suggested that 30 % of DM was a minimum level to reduce the undesirable growth of clostridia. Muck (1988) indicated that, with the increase of the DM concentration, the aqueous activity decreases progressively, reducing proportionately the growth of microorganisms such as clostridia. On the other hand, the NDF concentration, both at the beginning and end of the season, was within the range reported by Aguilera *et al*. (1997) for silages of Mexican Creole mango with maize stubble. In respect to the CP level, the data of this research were within the extreme values published by Aguilera *et al*. (1997) for ensilages of mango with urea (21.5-21.8 %) or without it (5.9-6.3 %).

The changes on the chemical characteristics of the silages in both harvest seasons could be, probably, due to the nature of the fruits used, that showed certain differences according to the harvest month, June or August (Guzmán 2010). The environmental temperature could be a factor that could have modified the fermentative process (McCullough 1975 and McDonald *et al*. 1981), but still, in this research there were no evidences of notable changes in the environmental temperature between days, although there did were in the daily cycle (vide supra).

It is known that there are factors of agricultural management that can be shown in the fruits characteristics (Yeshitela *et al*. 2005 and Quijada *et al*. 2009), but this aspect was not object of the present study. In fact, at present, there are no useful antecedents in the fruit variety studied. This could be attributed to the relatively short duration period of the seasoning of this fruit, limited in Nayarit to three months, from June to August. In Florida, place of origin of the variety assessed, June and July are the maturation months of the Tommy Atkins mangoes, although, in some seasons, it may occur in August (Campbell 1973 and Campbell and Campbell 1993). This period is similar to that indicated by Guzmán-Estrada (1997) in the south of Sinaloa, at north of Nayarit, and by Pérez *et al*. (2006) in Nayarit as such.

Effect of the preservation time. Generally, all the silages were stabilized in their chemical indexes from the seven and fourteen preservation days. Between the day zero and seven of preservation, the DM concentration of the silages diminished from 34.6 to 30.5 %. From this time on, it was permanent up to the 82 d of test.

There were only small variations evident in the levels of NDF and cellulose of the silages during the preservation time. The rest of the chemical indexes measured were constant. Aguilera *et al*. (1997) informed a similar response on the NDF concentration of the mango silage assessed. In this sense, it has been referred that during the silage process, cellulose and lignin are constant (van Soest 1994), agreeing with that found in this experiment. However, hemicellulose seems to be an additional source of carbohydrates (McDonald *et al*. 1991), apart from the soluble ones, which are preferably fermented (Woolford 1984). This can explain the variations of the NDF content found this study.

Effect of additives. According to Bolsen *et al*. (1996), the additives included in the silos preparation are characterized by a high concentration of fermentable carbohydrates, low buffering capacity, relatively low DM, between 20 and 30 %, and proper lactic bacteria. It is interesting to point out that mango residues have been used as additives for ensilaging more conventional materials to achieve proper indexes in the silos (Filho *et al*. 2010 and Rego *et al*. 2010) and vise verse, the residues with different additives (Filho *et al*. 2006). This last type of silage has been of the preparations in studies conducted in Mexico (Scotillo 1984 and Aguilera *et al*. 1997).

The inclusion of maize stubble in the silages determined an increase of the micro-silos DM concentration in the three treatments with rejected fruit, as well as in those three with industrial by-products of mango. Parallely, this stubble could act as an absorbent material of the silages drainage, as previously indicated (Aguilera *et al*. 1997). The proportions of mango products: maize stubble equal to 85:10 and 75:20 in fresh basis determined a DM concentration that was within the range considered optimum in the silos preparation (McDonald *et al*. 1991). In general lines, the maize stubble included in the silos did not show influence on the content of ADF, lignin and hemicellulose. However, the concentrations of NDF and cellulose showed variations, associated with the absence or presence of molasses in the material fermented. Actually, when including molasses in the silo, the concentrations of NDF and cellulose diminished, that could probably be an effect of the inclusion of maize stubble and molasses in the same material to be preserved. The presence of urea in the silos determined clearly an increase on the CP concentration of the product ensilaged. The ensilages of mango without urea showed very low levels of CP (4.82 and 5.42 %), and do not seem to be convenient for ruminants (Muck 1988 and Bolsen *et al*. 1996).

The use of waste fruits and industrial mango by-products ensilages is recommended for animal feeding, particularly in ruminants, with the addition of maize stubble between 10 and 20 %. Adding agricultural urea and sugar cane molasses, with 3 and 2 % of inclusion in fresh basis is suggested. The silos of mango wastes can be used at 21 d after their preparations, under the conditions as those described in this study. They would be of better quality if they were prepared at the end of the fruit season. These ensilages should be assessed in performance and determination tests of the nutritive value in ruminants.

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