UTILIZATION OF SWEET POTATOES (*Ipomoea batata* (L.) Lam) IN ANIMAL FEEDING III. ADDITION OF VARIOUS LEVELS OF ROOTS AND UREA TO SWEET POTATO FORAGE SILAGES[1]

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With the purpose of studying the fermentative conservation of sweet potato foliage, laboratory silos were prepared' each containing 4 kg of chopped foliage, allocated to 25 treatments resulting from the factorial combination of 5 levels of sweet potato roots (0, 3, 6, 9 and 12% of the ensiled material, on fresh basis) and 5 levels of urea (0, 0.4, 0.8. 1.2 and 1.6% of the material, fresh basis). Duplicate silos were used thus resulting in a total of 50 units.

The addition of urea caused a linear increment in pH and a quadratic increase in DM losses by putrefaction. However, no definite effects were detected with regard to acetic, butyric and lactic acids. The DM in vitro digestibility remained relatively constant around an overall average of 60.3%. The addition of roots had an acidifying effect which became more marked as the level of urea increased; however the extent of this effect was very modest when compared to the alkaline effect imparted by urea. There were no noticeable effects of root additions upon DM losses by putrefaction and lactic acid concentration. In general, the concentrations of acetic and butyric acids increased with additions of roots. The values for butyric acid changed from 1.07%, to 3.46% on dry basis, when the level of roots varied from 0 to 121, respectively. The in vitro DM digestibility of the ensiled material improved slightly when roots were added. The silages that contained no additives showed excellent characteristics; their pH values averaged 3.9 and the acid concentrations were 3.49%, 0.68%, and 5.21% for acetic, butyric and lactic acids, respectively. Losses of DM by putrefaction were low (11.6%) in these silages. In view of the results obtained when no additives were used and when urea or roots were added, it is concluded that silages of excellent quality can be obtained from sweet potato foliage as long as no additives, such as urea or roots, are used.

Key words: Sweet potato, aerial part silage, additives

Sweet potato (*Ipomoea batata* (L.) Lam) is one of the most widely cultivated crops on the small farms of Tropical America. After harvesting a large volume of forage consisting of stems and leaves, and a variable amount of non-commercial roots is left in the field, all of which could be utilized in the feeding of ruminants (Backer et al 1980). Some varieties of sweet potatoes can be grown two to three times per year, with yearly yields of up to 125 t of fresh biomass of which 64% is the aerial part (forage) (Pinchinat 1970). Chemical analyses of the aerial part have shown values of 12%-17% of crude protein, less than 18% fibre and a dry matter (DM) digestibility higher than 70% (Ffoulkes et al 1978; Ruiz et al 1980).

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In an experiment designed to evaluate the response of animals fed sweet potato roots and foliage it was found that the average daily intake was 2.37 kg DM/100 kg body weight and that this intake was independent of the ratio roots/foliage in the diet (Backer et al 1980). Also, it was found that the rate of weight gain increased from 0.65 kg to 0.82 kg/head/day as the proportion of roots in the diet increased from 0% to 60%, presumably as a result of a higher metabolizable energy intake. These findings were the basis for the proposal of a model integrating both agronomic and beef production aspects, based on the total utilization of the sweet potato foliage plus a minimum root residue of 12% of the total harvest, with a predictable profitability of 38% (Backer et al 1980).

One of the constraints for the use of sweet potato foliage in animal feeding is the fact that its availability is not constant throughout the year but, rather, it is concentrated in one or two harvests per year which, in general, do not coincide with the period of scarcity of pastures; it follows, then, that such biomass must be preserved either as hay or silage. In the humid tropics the first alternative is impractical due to difficulties for quick dehydration in the field; hence, silage-making is the obvious method of choice for forage conservation in the humid tropics although there exist certain inherent technical limitations that need be resolved.

The use of additives in silages, with a view to preservation of the nutritional value of the forage, has been amply studied. Urea as an additive has shown the property of raising the content of lactic acid up to 7.5% when added to sugar cane silages at a rate of 2% on a fresh basis (Lara y Lara 1977). On the other hand, it has been reported that urea may increase or decrease the concentration of acetic acid (Catchpoole 1970) and, apparently, it always causes an increase in the concentration of butyric acid (Barrett 1957), an undesirable acid because of its detrimental effect on voluntary intake. Moreover, increasing the level of urea has been associated with increments in the content of crude protein, total nitrogen, and ammonia nitrogen and losses of ensiled material, although these effects also depend upon the presence of rapidly fermenting carbohydrates (Barrett 1957; Gross 1969; Owens et al 1969; Mejia and Pineda 1973; Moreno 1977).

Most tropical forages are typically low in rapidly fermenting carbohydrates (Catchpoole 1970). Thus, in such silages, it is not possible to reach quickly the degree of acidity that is necessary to stop microbial activity, an essential condition for preservation of the nutritive value of the forage (Cherry 1970). Consequently, some research has been done with tropical grasses ensiled with local energy supplements such as molasses. In general, the addition of molasses has led to lower pH values, increments in protein content and a reduction in losses by putrefaction. Nevertheless, under hot and dry conditions in Panama, adding molasses to King grass (*Pennisetum purpureum* PI 300-086) silages has produced undesirable effects, notably carbonization of the material and high levels of butyric acid (Moreno 1977). Based on the above consideration, it is possible that sweet potato silages may require the addition of a source of readily fermentable carbohydrate . If such were the case, the crop itself could provide the required carbohydrate as roots. On the other hand, the addition of roots would cause a dilution effect on the N content of the silage and this situation would require the addition of urea. Thus the combination of urea, roots and sweet potato forage may have effects that demand an evaluation as presently described below.

Materials and Methods

Treatments and statistical design: Fifty polyethylene bags were used as micro-silos for the sweet potato forage, variety C-15; this forage contained 20% DM and 14.3% crude protein. Two additives were used in various concentrations: urea (0, 0.4, 0.8, 1.2 and 1.6% of the forage on fresh basis) and sweet potato roots (0, 3, 6, 9 and 12% of the forage on fresh basis), using a factorial arrangement of treatments within a completely randomized design.

Procedure: The forage was allowed to wilt in the field for 24 hours before chopping it in particles of 2 cm length. Each micro-silo contained 4 kg of fresh forage plus the corresponding amounts of the additives. The mixture was manually packed and each bag was hermetically sealed using a heat sealer; each bag was placed into another plastic bag which was also sealed.

Measurements: After 40 days, the micro-silos were open; immediately, the amount of rotted material was recorded according to visual inspection. From the center portion of the silo, samples were taken for DM determination by both toluene distillation and vacuum dehydration (Baseman 1971). The samples dehydrated under vacuum conditions were analyzed for crude protein content, using the micro-Kjeldahl method (Baseman 1971), and their in vitro digestibility was also determined by the two-stage technique of Tilley and Terry (1963).

Silage juice was extracted from approximately 500 g of fresh silage by using a hydraulic press. The juice was used to determine the pH and ammonia N, the latter by the AOAC formaldehyde method (1970). A portion of each extract, previously treated with toluene to stop further fermentation, was used to determine acetic, butyric and lactic acid contents. The determination of these acids required prior esterification with ethyl alcohol and extraction of the esters with benzene. The actual determinations were made with a flame detection gas chromatograph. Its stainless steel column (36.5 cm x 3.18 mm i.d.) was packed with 10% Cromosorb WHP mesh 60/80. The liquid phase consisted of Carbowax 20M. Oxygen-free nitrogen gas was used as the carrier.

Statistical analysis: : Although all treatments were applied to duplicate silos and a completely randomized design was used, the data was analyzed by regression as the main interest was in detecting trends and points of best response.

Results and Discussion

DM content of silage: The content of DM in the silages showed little variation, averaging 20.4% with a standard deviation of 2.00 (Table 1). Since the micro-silos were not fitted with a drainage system, the DM values reflect, to a great extent, the original values of dry matter in the fresh material (20% in forage and 30% in the roots of the sweet potato).

In spite of a 24-hour wilting period, the forage had a low percentage of DM, much lower than the 30% DM value recommended by several authors as necessary for a good-quality silage (Wieringa 1960; Catchpoole & Henzell 1971; Jones et al 1971). Woolford (1972) has indicated that as the water content of the material to be ensiled increases, more acid conditions must be reached in order to inhibit the secondary (butyric) fermentation caused by clostridia.

DM losses: From Table 1, it is apparent that the five sweet potato forage silages, without additions of urea, had on average very low losses of DM by putrefaction (only 9.2%). This result compares favorably with values obtained by Waldo (1977) of 13 to 15% with wilted forages, with no additives; 17 to 20% when the material is unwilled and without additives; and 10 to 15% in silages where additives were used. The low DM losses should not, nevertheless, be taken as absolute values singe the silos had no drainage. However, based on the data in Table 1 it should be noted that all silages, where no urea additions were made, were consistently better preserved than the silages that had urea.

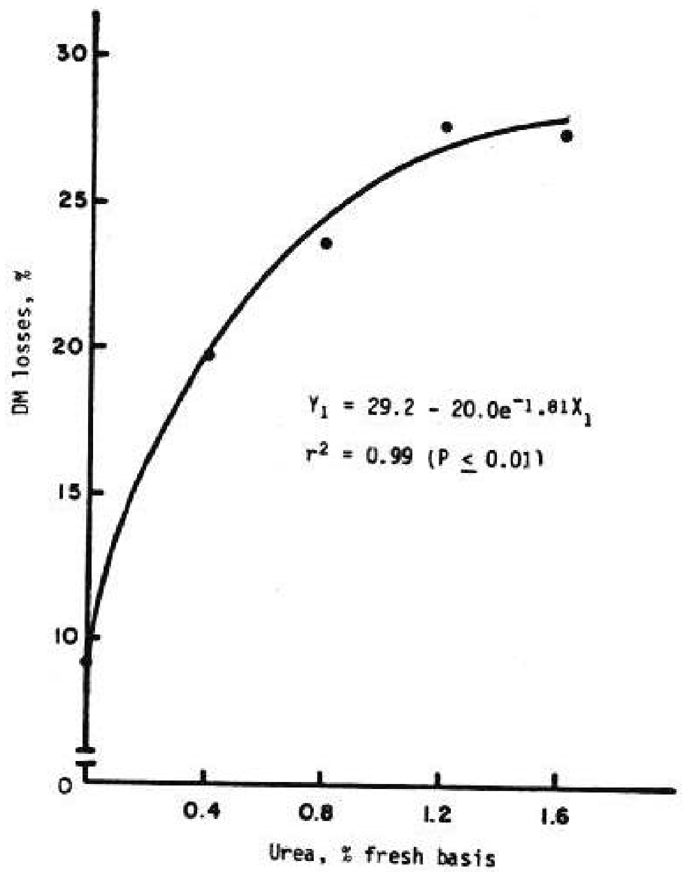
Table 1:

DM content and losses by putrefaction in sweet potato forage silages with various levels of addition of roots and urea

Variable	DM content %	DM losses %
Addition of roots, % fresh basis		
0	17.9	21.7
3	19.8	20.8
6	21.2	19.9
9	21.7	19.7
12	21.3	25.9
Addition of urea, % fresh basis		
0	21.2	9.2
0.4	20.1	19.7
0.8	20.8	23.6
1.2	19.2	27.8
1.6	20.6	27.7
Averages of all 25 treatments ± standard deviations	20.4 ± 2.00	21.6 ± 8.55

The addition of urea promotes losses of DM which may be as high as 28% (Table 1). Dry matter deterioration increases rapidly at low levels of urea and tends to plateau at high levels of urea; no apparent interactions with the addition of roots were found (Figure 1).

Figures 1 :
Dry matter losses in sweet potato forage silage containing urea

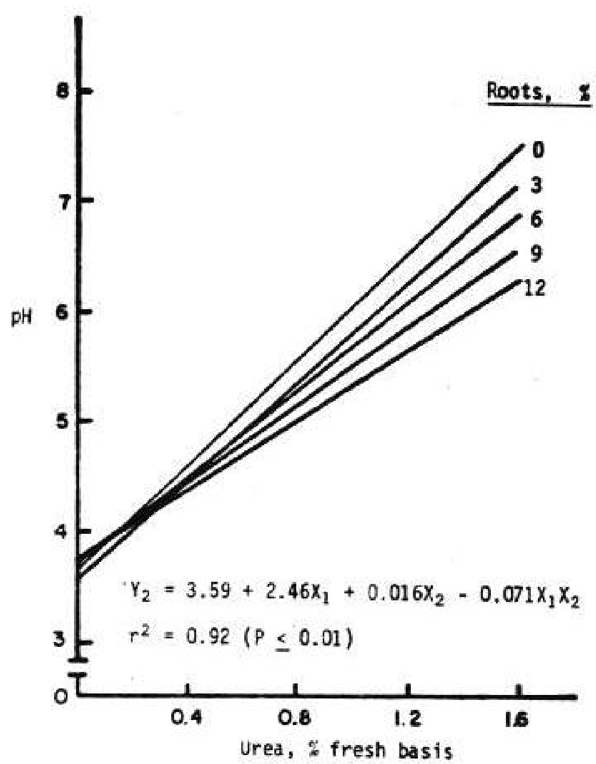


According to the results obtained, it is evident that urea has a detrimental effect upon the recovery of unspoiled silage; however, it must be recalled that the laboratory silos had no drainage and this may cause a distortion in the parameter being discussed. Nevertheless, Moreno (1977), working with field silos, obtained data which tend to confirm that adding urea to silages will cause larger losses due to spoiled DM. Unfortunately, the most recent literature does not include evaluations of DM losses by putrefaction as caused by additions of urea, or other additives, or by various manipulations (see, for example, the works by Marsh 1979; Singh & Pandit 1978;

Lessard et al 1978; Aguilera and O'Donouan 1975), thus no clear explanation of the effect of urea can be offered at this point. It is possible that the increases in pH, resulting from the additions of urea (Moreno 1977; Lara y Lara 1977; Singh y Pandit 1978), will result in sustained bacterial activity which is only inhibited when the pH reaches a value of 3.8 to 4.3, according to Wilkinson et al (1976) and Marsh (1979). Consequently, an undesirable fermentation by clostridia and molds would ensue, resulting in DM losses by putrefaction. Britt & Huber (1975) found a positive correlation between pH and number of mold colonies although they also pointed out that the increase in pH (as caused by additions of NH3) does not totally explain the proliferation of molds.

pH: The relations between the factors under study, and the acidity of the silage, are shown in Figure 2. The sweet potato forage silages, where no additives were used, showed a pH of 3.9 which is compatible with good quality silages (Wilkinson et al 1976); among the silages without urea, but with various levels of roots, the pH ranged from 3.7 to 3.9, although the regression shown in Figure 2 predicts an average value of 3.6.

Figure 2:
pH in sweet potato forage silage as affected by urea (X1) and chopped roots (X2)



The results in Figure 2 indicate that in the absence of or with minimal levels of urea, adding chopped roots does not improve the quality of the silage. With the higher levels of urea, the acidifying effect of the roots become increasingly evident (Figure 2). However, the alkaline effect of urea is so dominant that little is achieved by adding roots to the urea-containing silages. These results are in agreement with those obtained by Lara y Lara (1977) in sugar cane silages with additions of urea and molasses. In contrast, Singh & Pandit (1978) found that the addition of molasses failed to counteract the alkaline effect of urea in sorghum silages and that, in fact, the molasses tended to enhance the effect of urea on the pH.

As was indicated previously, a pH higher than 4.3 increases the probabilities of undesirable fermentations. Clear evidence in this respect was offered by Schultz et al (1974), who found undesirable fermentation characteristics in ryegrass hay silages with additions of molasses, urea and limestone.

In the context of the discussion and in the light of the observed changes in pH, it appears that the use of urea as a silage additive is not to be recommended.

Organic acids: acetic, butyric and lactic: The analyses of each of these acids produced highly variable data (Table 2). Applying a quadratic model, including both independent variables, to each set of 25 data, it was found that less than half of the total variation could be explained by the regression model (r^2 = 0.47, 0.45 and 0.23 for the acetic, butyric and lactic acids data, respectively). In the cases of the acetic and butyric acids the only significant coefficient was the one corresponding to the lineal effect of the level of roots; for this reason, a linear regression model was applied to the averages for the said variable, for each of the two acids aforementioned. The results are presented in Figure 3.

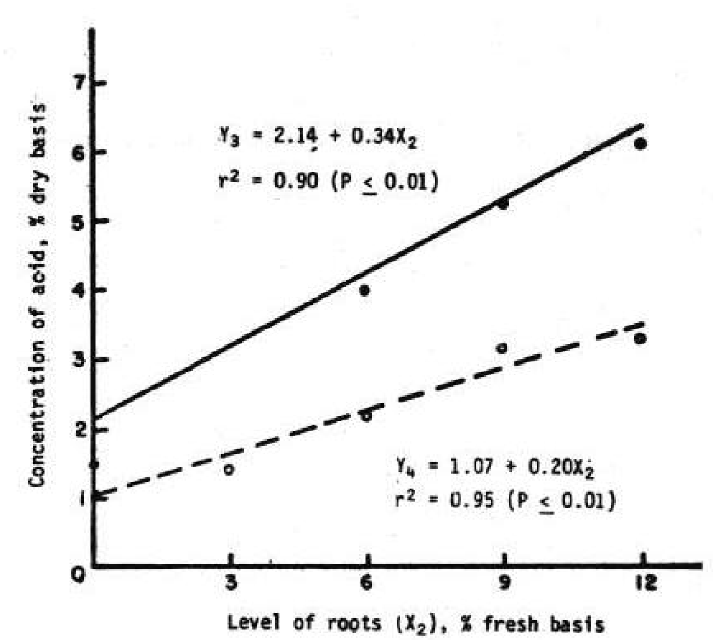
Table 2:

Concentration of acetic, butyric and lactic acids in sweet potato forage silages containing various levels of chopped roots and urea

Variable	Acid content, % dry basis		
	Acetic	Butyric	Lactic
Addition of roots, % fresh basis			
0	1.54	1.14	2.09
3	4.09	1.48	2.64
6	4.02	2.24	4.02
9	5.24	3.18	0.49
12	6.14	3.28	0.83
Addition of urea, % fresh basis			
0	4.26	1.65	1.88
0.4	5.05	2.14	1.69
0.8	5.81	2.88	3.17
1.2	3.06	2.46	2.25
1.6	2.85	2.20	1.07
Averages of all 25 treatments ± standard deviations	4.21 ± 2.79	2.26 ± 1.41	2.01 ± 2.27

From Figure 3 it is apparent that the addition of chopped sweet potato roots promotes fermentation as expected. With higher production of acids the pH value diminished accordingly, as was observed in Figure 2; this effect of the presence of roots in the silages was more evident as the level of urea increased. Attention must be called to the fact that the values used for the regressions in Figure 3 would correspond to an average of 0.8% urea in all silages (since each value was obtained by averaging all data within each level of roots but across all 5 levels of urea).

Figure 3:
Changes in the concentration of acetic acid (---) and butyric acid (- -) in sweet potato forage silage as caused by additions of sweet potato roots.



Based on criteria for differentiating good from poor quality silages (Barrett 1957), it can be stated then that all silages with additives exceeded the maximum of 1% butyric acid allowed in good quality silages. Evidently, adding chopped roots caused a further deterioration in this respect. Although it was not shown either in Table 2 or in Figure 3, the forage silages without additives contained only 0.68% butyric acid and had 3.49% acetic acid and 5.21% lactic acid, on a dry matter basis.

With respect to acetic acid, there are no norms indicating optimum or maximum values in good quality silages, although as low a concentration as possible is generally preferred. On the other hand, it is known that acetic acid acts as a preservative and, as such, it may play a beneficial role in silages (Woolford 1972). However, it is clear in the present study that the production of acetic acid is positively correlated with that of butyric acid (Figure 3) which is not desirable.

Finally, it can be stated that the lactic acid concentration did not serve as a parameter for the evaluation of the effects caused by the additives on silage quality due to the erratic trends (Table 2); it is only necessary to point out that most values were within the range of 3 to 13% that Barnett (1957) indicates as desirable in good quality silages.

In vitro digestibility: The addition of urea to the silages did not affect the in vitro DM digestibility, while the addition of roots caused a slight improvement in this parameter (Table 3). The latter is explainable, for the most part, by the fact that the sweet potato roots are more digestible than the aerial part (Ruiz et al 1980), and the effect of roots on DM digestibility is nearly a simple weighted average.

Table 3:
In vitro digestibility of sweet potato forage silages with various additions of roots and urea

Variable	DM digestibility %
Addition of roots, % fresh basis	
0	59.1
3	57.3
6	59.8
9	62.8
12	62.3
Addition of urea, % fresh basis	
0	59.3
0.4	60.3
0.8	59.7
1.2	60.4
1.6	61.3
Average of all 25 treatments ± standard deviation	60.3 ± 2.78

Unfortunately, no digestibility data were obtained of the forage prior to ensiling which would have made it possible to assess the changes in this parameter due to the fermentation process. If the value of 72.3% DM digestibility is taken as a reference point for the C-15 variety (Ruiz et al 1980) it would appear, then, that the silage fermentation process caused an important reduction in digestibility. Support for this possibility may be found in the results obtained by Dijkstra (1957) and Demarquilly and Jarrige (1970), although Harris and Raymond (1963) have pointed out that, in certain cases, the digestibility is not really altered when the digestibility values are corrected taking into account the volatile acids produced.

Conclusions

According to the results presented, the conservation as silage of the sweet potato tops is deemed as a meritorious alternative as long as no addi fives, such as urea or roots, are used. The sweet potato forage silage, when no additives are used, reaches an adequate acidity (pH 3.7) and the concentration of butyric acid remains low (0.68%), a fact that would ensure acceptability by livestock. Moreover, the concentration of lactic acid is satisfactory (5.21%), losses of spoiled material is minimal (11.6%) and the in vitro DM digestibility is high (59%).

The addition of urea to silages increases the losses of material by spoilage, possibly due to the alkaline effect of urea. The addition of roots does not cause effects of any practical importance, although this tends to improve some silage characteristics but have the undesirable effect of increasing the butyric acid concentration.

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