Scientific Paper

Fermentative quality of sorghum (*Sorghum bicolor* L. Moench) and citrus fruit (*Citrus* sp.) pulp silage▲

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Abstract

In order to characterize the fermentation dynamics of a silage of whole sorghum plant (*Sorghum bicolor* L. Moench) with inclusion levels of citrus fruit (*Citrus* sp.), pH, ammonia content and concentration of volatile fatty acids (acetic, propionic and butyric) were evaluated as quality indicators. A complete randomized design was applied with four treatments: a) 100 % sorghum, b) 75 % sorghum: 25 % pulp; c) 50 % sorghum: 50 % pulp, d) 25 % sorghum: 75 % pulp. Four moments were established (14, 28, 42 and 56 days) with six repetitions for each one. The silages showed pH between 3,29 and 4,32. A decrease of this indicator was observed, as the pulp percentage in the mixture increased. The silages with pulp reached the lowest pH values at 56 days of evaluation; while the sorghum silage (100 %) achieved them at 42 days. The ammoniacal nitrogen, just like pH, decreased with the inclusion of the pulp, and increased as the evaluation moments passed, with contents between 0,05 and 2,54 mg $N\text{-}NH_3$ 100 mL^{-1}. With regards to the volatile fatty acids, acetic acid showed the highest concentrations in all the silages during the evaluation period, with values between 1,7 and 17, 2 mmole L^{-1}. The quantities of propionic and butyric acid were negligible, and were in the range of 0,015 and 0,33 mmole $L^{-1}$for propionic and 0,004 and 0,037 mmole L^{-1} for butyric. There were significant differences in the production of acetic and butyric acid among the treatments since day 28 of the evaluation. Propionic acid showed differences since day 42. It is concluded that the fermentation quality indicators are within the established range to classify silages as having good quality.

Keywords: volatile fatty acid, ammonia, silage, pH

Introduction

In the tropic, ruminant feeding is based, fundamentally, on pasture and forage consumption. However, the climate conditions that exist in the region influence pasture growth and productivity. The annual distribution of rainfall, mainly, determines the good forage availability in the rainy season, in contrast with its scarcity in the dry season (Ku Vera, 2010; Canesin, 2014). With forage scarcity in the dry season, livestock experiences important weight losses, which affect its productivity, health and reproduction (Asaolu *et al.,* 2015).

These conditions impose the search for technological feeding alternatives for livestock that do not represent competition for humans, and which are economically feasible and environment-friendly, besides contributing to reduce costs and not complicating the management system in the farms, and in turn improve their efficiency (Campos-Granado and Arce-Vega, 2016).

The utilization of feed sources based on silage, hay and agroindustrial byproducts is a choice that allows to correct, at low cost, the nutritional deficiency of the herd (Asar *et al.,* 2010) and obtain products in higher quantity, with high biological value during conservation (Fernández-Herrero *et al.,* 2013). These feeding alternatives allow to reduce the nutrient loss due to the fast deterioration of forages when conservation is not done under adequate conditions, besides compensating their production costs (Miranda-Yuquilema *et al.,* 2014; Ali *et al.,* 2014).

The elaboration of silages allows the conservation of the forage excess produced during the rainy season so that it can be used in the lower availability season, without causing large transformations in

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the nutritional quality of the feedstuff (Morales *et al*., 2017).

The objective of the study was to characterize the fermentation dynamics of silage from whole sorghum (*Sorghum bicolor* L. Moench) plant with inclusion levels of citrus fruit (*Citrus* sp.) pulp.

Materials and Methods

The work was conducted with the whole sorghum (*S. bicolor* cv. UGD-110) plant, sown in experimental areas of the Pastures and Forages Research Station Indio Hatuey (EEPFIH), on a Ferralitic Red soil, of good surface and internal drainage and uniform profile (Hernández-Jiménez *et al.,* 2015). It was sown by drilling, at a distance of 1,0 m between rows, with doses of 20 kg ha^{-1}. It was fertilized with organic matter. The forage was harvested at the beginning of flowering, approximately between 65 and 70 days after sowing.

The citrus fruit residues were collected in status of commercial maturation at the Citrus Fruit Enterprise of Jagüey Grande, Matanzas province. The samples were subject to a manual cleaning process to eliminate any kind of dirt. In addition, the damaged or disturbed parts were removed.

For elaborating the silages, the whole sorghum plant was pre-wilted under shade during 48 h, todecrease moisture and reach a dry matter (DM) value higher than 30 %. Afterwards, it was chopped in a mill for forage until reaching a particle size of 4-5 mm, approximately. The citrus fruit pulp and sorghum were combined in three proportions (table 1).

Table 1. Proportion of whole sorghum plant and citrus fruit pulp for elaborating the microsilos.

Treatment	Description
A	100 % sorghum
B	75 % sorghum: 25 % pulp
C	50 % sorghum: 50 % pulp
D	25 % sorghum: 75 % pulp

The trials were conducted in the laboratory of feed evaluation of the EEPFIH and in the physiology laboratory of the Institute of Animal Science (ICA).

Treatment and experimental design. To evaluate the effect of the different formulations on the fermentative quality of silages, a complete randomized design was applied with four treatments (A, B, C and D), four moments (14, 28, 42 and 56 days) and six repetitions. The microsilo was considered the experimental unit.

Evaluation of fermentative quality. The silages were monitored at 14, 28, 42 and 56 days after their elaboration. To determine the acidity degree (pH) through the potentiometric method. Besides, the ammoniacal nitrogen content (Chaney and Marbach, 1962) and the concentration of volatile fatty acids (Cottyn and Boucqué, 1968) were determined.

Statistical analysis. For analyzing the data of the fermentative process dynamics, a linear model of SAS® (SAS, 2007) was used. When differences were found ($p < 0,05$), the means of the treatments were compared through Duncan's multiple range test.

Results and Discussion

For silage to be considered of good quality, it is necessary that it preserves, as much as possible, the nutritional characteristics of the original material. This occurs when reductions are achieved in the respiration of plant tissue, in the proteolytic activity and the development of clostridia, which is obtained with the fast decrease of pH after ensiling (McDonald *et al.* 1991).

Table 2 shows the pH of the studied silages. Trend to its decrease could be observed with the increase of the citrus fruit pulp level and time. According to Garcés Molina *et al.* (2005), the production of lactic acid and other acids allows fermentation to be successfully developed and the proliferation of the activity of lactic acid bacteria (LAB), these last ones becoming the prevailing population. Under such conditions, pH decreases between 3,8 and 5,0 depending on the forage species and characteristics.

Sánchez (2018) reports that the recommended pH for obtaining good-quality silages is 4,0. According to Moura *et al.* (2017), this value indicates that ensiled forages show sufficient quantities of soluble carbohydrates and that their fermentation guarantees the adequate conservation of the plant material through lactic acid production.

Ammonia showed trend to increase, as the inclusion level of citrus fruit pulp was reduced (table 3). Likewise, it increased from day 14 to day 56. Nevertheless, this increase was probably due to the ammonia generated by proteolysis processes, present during the first stages of silage production.

The expected values of ammoniacal nitrogen for good-quality silage vary according to the forage type (Jones *et al.,* 2004). Lower concentrations than

Table 2. Value of pH of silages from whole sorghum plant and citrus fruit pulp.

Treatment	Moments, days			
	14	28	42	56
100 % sorghum	4,24[c]	4,32[c]	4,07[c]	4,18[c]
75 % sorghum: 25 % pulp	3,86[b]	3,82[b]	3,90[bc]	3,78[b]
50 % sorghum: 50 % pulp	3,62[a]	3,58[a]	3,64[ab]	3,47[a]
25 % sorghum: 75 % pulp	3,58[a]	3,42[a]	3,49[a]	3,29[a]
SE ±	0,025	0,058	0,122	0,065
P-value	<0,0001	0,0002	0,0547	0,0003

a, b, c: Different letters indicate differences among treatments in the same column ($p < 0,05$)

Table 3. Ammonia content (mg N-NH_3 100 mL^{-1}) in silages of whole sorghum plant and citrus fruit pulp.

Treatment	Moments, days			
	14	28	42	56
100 % sorghum	2,13[d]	2,09[d]	1,98[d]	2,54[d]
75 % sorghum: 25 % pulp	1,06[c]	0,81[c]	1,37[c]	1,39[c]
50 % sorghum: 50 % pulp	0.55[b]	0,52[b]	0,84[b]	0,87[b]
25 % sorghum: 75 % pulp	0,05[a]	0,17[a]	0,29[a]	0,36[a]
SE ±	0,021	0,092	0,011	0,015
P-value	0,0805	<0,0001	<0,0001	<0,0001

a, b, c, d: Different letters indicate differences among treatments in the same column ($p < 0,05$)

11 % are qualified as acceptable silages: while the bad-quality ones are related to higher values than 15 % of ammoniacal nitrogen. Ojeda *et al.* (1991) indicated that, in well-preserved silages, the concentration of ammoniacal nitrogen with regards to the total should be lower than 7 %. In this study, the ammoniacal nitrogen values were not higher than 3 %. These results are not in correspondence with the report by Roa and Galeano (2015), who evaluated the effect of conservation time on the nutritional quality and *in situ* digestibility of silages from four forage woody plants. These authors refer concentrations of ammoniacal nitrogen lower than 1 %.

Figure 1 shows the production dynamics of volatile fatty acids (VFA) during the evaluation process. The acetic acid production did not differ at 14 days (figure 1.1). However, there were significant differences since 28 days of fermentation (figure 1.2), moment at which the silage with 75 % citrus fruit pulp reached higher concentration with regards to the others; while at 42 and 56 days, the treatment with 50 % pulp showed the highest acetic acid production, followed by the treatment with 25 % pulp, which exceeded the others.

The production of propionic acid did not differ until 42 days of fermentation (figure 1.3), moment at which the treatments with 50 and 75 % citrus fruit pulp produced more of this compound compared with the others. Nevertheless, at 56 days it was observed that only the treatment with 50 % pulp surpassed the rest (figure 1.4).

Regarding the production of butyric acid of the evaluated silages since 28 days, there was a decrease of this metabolite (figure 1.2), as the proportion of citrus pulp in the ensiled mixture decreased. The concentration of this VFA varied from 0,004 to 0,034 mmole L^{-1}, which according to Ojeda *et al.* (1991) is negligible in good-quality silages. Similar results were reported by Noguera *et al.* (2014), when evaluating the effect of different additives on the nutritional quality and the fermentation profile of the silage of passion fruit (*Passiflora edulis* Sims.) peels.

Conclusions

From the point of view of the fermentative process, in the studied silages, the pH values, ammonia concentrations and VFAs (acetic, propionic and

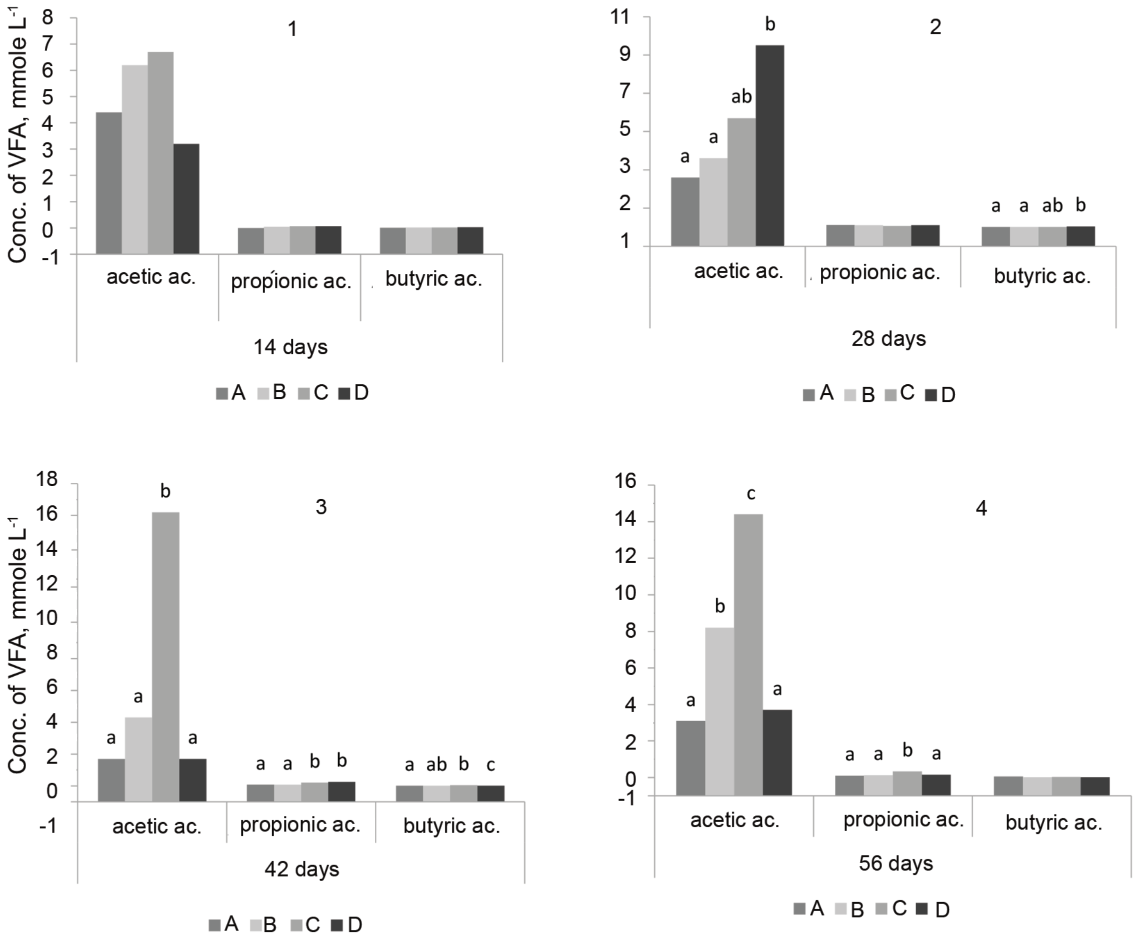

Figure 1. Production dynamics of acetic, propionic and butyric acid (mmole L-1) in silages of whole sorghum plant and citrus fruit pulp.

butyric), are within the established parameters for considering them of good quality.

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