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# Fermentative and organoleptic quality of silages with different proportions of forage and root from *Manihot esculenta* Crantz

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## Abstract

**Objective**: To evaluate the fermentative and organoleptic quality of silages with different proportions of forage and root of two varieties of *Manihot esculenta* Crantz in Matanzas province, Cuba.

**Materials and Methods**: A study was conducted in the nutrition laboratory of the Pastures and Forages Research Station Indio Hatuey, where the fermentative quality of two *M. esculenta* varieties (INIVIT Y-93-4 and Señorita), as well as the organoleptic quality of the produced silage, was evaluated. A complete randomized design was applied with three treatments, where each variety was evaluated separately: T1) 0 % foliage: 100 % root; T2) 25 % foliage: 75 % root and T3) 100 % foliage: 0 % root, at four moments of evaluation. Variance analysis was carried out and to determine the difference among means Duncan's test was used. The data were processed through the statistical package SPSS®.

**Results**: In all the treatments of the variety INIVIT Y-93-4, the highest temperatures were obtained at 15 days after starting the ensiling process, with values of 27,0; 26,9 and 26,7 ºC for T3, T1 and T2, respectively. However, the performance for the variety Señorita was different, with the highest temperature values (29,0 ºC) at the end of the process. Significant differences ($p \leq 0,001$) were also found in the concentration of $N\text{-}NH_3$ among the treatments in both varieties. The highest values (between 1,3 and 1,9) were obtained in T3, with regards to T1 and T2, which, in turn, differed between them.

**Conclusions**: The silage fermentation dynamics, with different proportions of forage and root from *M. esculenta* of the variety INIVIT Y-93-4, reached adequate temperature, pH and $N\text{-}NH_3$ parameters. The silages of both varieties did show good organoleptic characteristics.

**Keywords**: ammonia, silage, pH

## Introduction

*Manihot esculenta* Crantz (cassava in Cuba) is a tropical plant, efficient in the transformation of solar energy into nutrients utilizable by man. It is cultivated in America and Tropical Africa, mainly, as part of the subsistence agriculture (FAO, 2018). If compared with other roots and tubers, it is the one that shows higher growth rate of annual consumption, with 1,9 % and the second place in terms of forage production, with 0,95 % in the America region (Santos *et al*., 2019).

*M. esculenta* can be an excellent substitute of *Zea mays* L. (corn) in the diet, as it is a crop with high production of roots, rich in starch, and of foliage, with high protein percentage (Aguilar-Martínez, 2017; Connolly-Juárez, 2017; Celis *et al*., 2019; López-Herrera *et al*., 2019). From the experience in the use of this plant in different countries, it is known that it can be utilized in substitution levels (40,0 % and more) in the feeding of cattle for milk and beef production (Vera-Arteaga *et al.,* 2019), as well as in pigs (Romero-de-Armas *et al*., 2017) and poultry for meat and eggs (Gámez-Hernández, 2020).

The *M. esculenta* silage could be a viable alternative for feeding livestock at times of feed scarcity, where there is the opportunity to supply a product with similar characteristics to its fresh status (Caicedo and Flores, 2020). It is known that silage is the fermentation of soluble carbohydrates of forage through bacteria that produce lactic acid under anaerobic conditions, which is used to increase the nutritional value of agricultural products and residues (Chafla *et al*., 2015) and to preserve feedstuffs with high carbohydrate content, which are ensiled alone or fermented with other products (Díaz-Monroy *et al*., 2018; Pascual-Sánchez *et al*., 2019; Caicedo and Flores, 2020).

The foliage of this plant, combined with its root in different proportions, and following the practices

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recommended for the elaboration of silages in general, would result in a high-quality product. The silage, with progressive quantities of root, would be a product with higher energy content, or on the contrary, silage with more protein, for which it could be offered to animals with different nutritional demands.

The objective of this work was to evaluate the fermentative and organoleptic quality of silages with different proportions of forage and root of two *M. esculenta* varieties in Matanzas province, Cuba.

## Materials and Methods

*Location*. The study was conducted in the Nutrition laboratory of the Pastures and Forages Research Station Indio Hatuey, located between 22° 48' 7" North latitude and 81° 2' West longitude, at 19,01 m.a.s.l., in the Perico municipality, Matanzas province, Cuba.

*Plant material*. The material (foliage and root) came from two *M. esculenta* varieties (INIVIT Y-93-4 and Señorita), from the Tropical Root and Tuber Crop Research Institute (INIVIT, for its initials in Spanish) of Santo Domingo, Villa Clara province. Planting was done manually on a Ferralitic Red soil (Hernández-Jiménez *et al*., 2015), placing the stakes horizontally at the center of the ridge of seven rows 10,0 m long, with planting frame of 0,90 x 1,0 m. Neither irrigation nor fertilization was used, the crop was not weeded either after being sown. The harvest moment was 8 and 12 months for the variety INIVIT Y-93-4 and Señorita, according to the technical instruction manual of the species, as they are short- and long-cycle varieties, respectively.

*Experimental design and treatments*. In order to evaluate the effect of the different formulations on the fermentative and organoleptic quality of the silages of the two studied varieties, a complete randomized design was used with three treatments: T1-0 % foliage: 100 % root; T2-25 % foliage: 75 % root and T3-100 % foliage: 0 % root. Four evaluation moments (15, 30, 45 and 60 days) and six repetitions for each moment were established. The bag microsilo was considered as the experimental unit.

*Experimental procedure*. For the elaboration of the microsilos, the plant material and the root were separately chopped in a mill for Saccharine, model B-625, until reaching particle size of 4,0-5,0 mm, approximately. Afterwards, it was homogeneously mixed, depending on the experimental proportions, and it was placed in polyethylene bags, 12,0 cm wide by 24,0 cm long. The material was compacted well inside the bag, taking care of not perforating it. At the end, each microsilo was airtight sealed with the aid of duct tape. The obtained microsilos were kept under those conditions for 60 days, in a fresh and protected room. Twenty four microsilos were produced per treatment, with weight of 500,0 g per microsilo as average.

*Quality analysis*. The silage was monitored at days 15, 30, 45 and 60 after its elaboration to determine the fermentation dynamics. For such purpose a scale of laboratory silages, proposed by Ojeda *et al*. (1991), was used. The fermentative quality of the silages was determined from three indicators: acidity degree (pH), which was determined with a potentiometer on an aqueous extract, formed by a faction of 25,0 g of silage and 250,0 mL of distilled water, after one hour of resting (Cherney and Cherney, 2003); the temperature, which was studied according to O´Kiely *et al.* (2001) and ammoniacal nitrogen (Chaney and Marbach, 1962). In addition, upon opening the microsilos at 60 days, their organoleptic characteristics (color, smell and texture) were evaluated, according to the evaluation table proposed by Betancourt *et al.* (2005).

*Statistical processing*. The data were processed through the statistical package SPSS®, version 22.0 for Windows®. Variance analysis was carried out, after testing the variance homogeneity and data normality assumptions. The difference among means was determined through Duncan's test. The correlation and regression analysis was used to know the interrelation between the variable pH and ammoniacal nitrogen with the treatments. As selection norm of the best-fit equation the significant level and that the determination coefficient ($R^2$), real and adjusted, was higher than 0,70, were considered (Guerra *et al*., 2003).

## Results and Discussion

Tables 1 and 2 show the organoleptic characteristics of the evaluated silages of the varieties INIVIT Y-93-4 and Señorita, respectively. The smell and texture showed excellent quality, according to the indicators proposed by Betancourt *et al.* (2005), independently from the raw materials and the combination between them. Regarding the color, T1 showed a dark-yellow shade, maybe due to the presence of root alone in the silage, which turns it into a good-quality product. Meanwhile, in T2 and T3, the color was olive-green, which was more stressed in T3, due to the absolute increase of *M. esculenta* foliage, for which they achieved evaluation of excellent. This

Table 1. Organoleptic characteristics of the silage of forage and root from *M. esculenta*, variety INIVIT Y-93-4.

| Indicator | Treatment | | |
|---|---|---|---|
| | T1-0 % foliage:100 % root | T2-25 % foliage:75 % root | T3-100 % foliage:0 % root |
| Color | Dark yellow | Olive green | Olive green |
| Smell | Of ripe fruit | Of ripe fruit | Of ripe fruit |
| Texture | It preserves its continuous contours | It preserves its continuous contours | It preserves its continuous contours |
| Quality | Good | Excellent | Excellent |

Table 2. Organoleptic characteristics of the silage of forage and root from *M. esculenta*, variety Señorita.

| Indicator | Treatment | | |
|---|---|---|---|
| | T1-0 % foliage :100 % root | T2-25 % foliage: 75 % root | T3-100 % foliage: 0 % root |
| Color | Dark yellow | Olive green | Olive green |
| Smell | Of ripe fruit | Of ripe fruit | Of ripe fruit |
| Texture | It preserves its continuous contours | It preserves its continuous contours | It preserves its continuous contours |
| Quality | Good | Excellent | Excellent |

organoleptic performance of the silages was similar in both varieties.

Similar results were reported by Maza *et al.* (2011) in a study of evaluation of the chemical composition and of the organoleptic characteristics of *Pennisetum* sp. silage with different proportions of fresh *M. esculenta*. In their research, the control treatment showed a yellowish-green color.

The pertinent presence of lactic acid in the silages allowed the stability of these last ones and, in turn, determined the sweet smell and pH lower than 4,5 (Adams and Moss, 1997). Likewise, the texture of silages in all the treatments showed continuous contours, condition that qualifies silages of excellent quality, and which also proves that there was no degradation of the ensiled material.

Tables 3 and 4 show the temperature values of the silages, for the varieties INIVIT Y-93-4 and Señorita, respectively.

For INIVIT Y-93-4 (table 3), the values were found between 22,0 and 27,0 ºC throughout the fermentation process. In all the treatments, the highest temperatures were obtained 15 days after beginning the ensiling process, with values of 27,0; 26,9 and 26,7 ºC for T3, T1 and T2, respectively. The temperature decreased as the fermentation days increased, with the exception of day 45, in which a slight increase was observed, but without significant differences among treatments. At the moment of opening the silages (day 60), the temperature fluctuated between 22,2 and 22,6 ºC, with higher value ($p < 0,001$) also in T3.

Regarding the variety Señorita (table 4), throughout the fermentation process, the values varied between 23,0 and 29,0 ºC. It was proven that the temperature increased with the days of fermentation. At 15 days, the lowest temperature values were found, with highly significant differences

Table 3. Temperature value of the silage of forage and root from *M. esculenta*, variety INIVIT Y-93-4.

| Treatment | Moments, days | | | |
|---|---|---|---|---|
| | 15 | 30 | 45 | 60 |
| | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE |
| T1-0 % foliage: 100 % root | $26,9^{a} \pm 0,045$ | $24,1^{a} \pm 0,123$ | $25,3 \pm 0,061$ | $22,2^{b} \pm 0,041$ |
| T2-25 % foliage: 75 % root | $26,7^{a} \pm 0,087$ | $22,9^{b} \pm 0,097$ | $25,0 \pm 0,034$ | $22,3^{b} \pm 0,061$ |
| T3-100 % foliage: 0 % root | $27,0^{b} \pm 0,065$ | $22,9^{b} \pm 0,087$ | $25,2 \pm 0,077$ | $22,6^{a} \pm 0,034$ |
| P - value | 0,01 | 0,000 | 0,129 | 0,000 |

a, b and c: different letters in the same column differ at $p < 0,05$

Table 4. Temperature value of the silage of forage and root from *M. esculenta*, variety Señorita.

| Treatment | Moments, days | | | |
|---|---|---|---|---|
| | 15 | 30 | 45 | 60 |
| | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE |
| T1-0 % foliage: 100 % root | 23,4$^{b}$ ± 0,052 | 25,5 ± 0,083 | 27,7$^{a}$ ± 0,106 | 29,0 ± 0,041 |
| T2-25 % foliage: 75 % root | 23,1$^{c}$ ± 0,026 | 25,7 ± 0,041 | 27,8$^{a}$ ± 0,050 | 29,1 ± 0,062 |
| T3-100 % foliage: 0 % root | 23,5$^{a}$ ± 0,020 | 25,6 ± 0,085 | 27,4$^{b}$ ± 0,042 | 29,1 ± 0,047 |
| P - value | 0,000 | 0,285 | 0,005 | 0,417 |

a, b and c: different letters in the same column differ at p < 0,05

among the treatments (p < 0,001). However, at 30 and 60 days of fermentation, the treatments did not differ among them, and the highest temperatures were obtained 60 days after beginning the ensiling process, in the order of 29,13; 29,12 and 29,04 ºC for T3, T2 and T1, respectively.

These results, related to the temperature of the variety INIVIT Y-93-4, coincide with the report by Villalba *et al.* (2011), who evaluated the bromatological and organoleptic quality of silages of organic residues of the coffee-banana production system.

In the first phase of the silage, according to the report by Ferrari and Alarcón (2015), due to the respiration of plant cells, temperature increase is generated, in a range from 4 to 6 ºC over ambient temperature. This coincides with the findings in all the treatments of the variety INIVIT Y-93-4, in which during the first 15 days of the fermentation process the highest temperature values were recorded (table 3). These cells breathe until they consume all the $O_2$ present in the ensiled material, producing heat, $H_2O$ and $CO_2$ (Blanco-Valdes *et al.,* 2016). In addition, on the surface of plants, groups of microorganisms are found which belong to the epiphytic microbiota (bacteria, fungi and yeasts), which generate an important microbiological and enzymatic activity, by producing heat and the most important acids of fermentation (Zahiroddini *et al.,* 2004).

The behavior of the variety Señorita was different from the one observed in INIVIT-Y-4 (table 5), although it was similar to the one reported by Morales-Querol (2020) under analogous conditions to the ones in this research, with proportions of sorghum [*Sorghum bicolor* (L.) Moench] and citrus pulp (*Citrus* sp.) similar to the ones evaluated here. This author stated that the increasing rise of temperature, as the evaluation days increase, is due to the ambient temperature of the evaluation moment, which influenced the final temperature of the silage; hence, its high temperatures.

In the silage of the variety Señorita, as it is of long cycle, the evaluation started at the beginning of the rainy season (May-June), when the ambient temperature is, as average, 27 ºC (Ruz-Suárez *et al*., 2021). Meanwhile, in INIVIT-Y-4, it was evaluated during the dry season (November-December), with lower ambient temperatures.

According to Reyes *et al.* (2009), the acceptable temperature range is 30-40 ºC. Higher values than 40 ºC during the silage stabilization indicate that the compaction has not been sufficient, and that there is the possibility of air entrance. Likewise, an equal or slightly higher temperature than the

Table 5. pH value of silages of forage and root from *M. esculenta*, variety INIVIT Y-93-4.

| Treatment | Moments, days | | | |
|---|---|---|---|---|
| | 15 | 30 | 45 | 60 |
| | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE |
| T1-0 % foliage: 100 % root | 3,7$^{b}$ ± 0,003 | 3,7$^{b}$ ± 0,009 | 3,7$^{c}$ ± 0,003 | 3,7$^{b}$ ± 0,007 |
| T2-25 % foliage: 75 % root | 3,8$^{b}$± 0,009 | 3,8$^{b}$ ± 0,010 | 3,9$^{b}$ ± 0,020 | 3,8$^{b}$ ± 0,012 |
| T3-100 % foliage: 0% root | 4,3$^{a}$ ± 0,059 | 4,3$^{a}$ ± 0,066 | 4,3$^{a}$ ± 0,022 | 4,5$^{a}$ ± 0,079 |
| P - value | 0,000 | 0,000 | 0,000 | 0,000 |

a, b and c: different letters in the same column differ at p < 0,05 ambient one indicates an adequate stabilization of the fermentation process, which is shown in this study. Anaerobic fermentation, being a biological process, is related to the ambient temperature and to the heat generated in such process. It is valid to explain that all the silages of the two varieties had excellent quality (tables 1 and 3). They did not show deterioration due to excessive heating, like the presence of mildew on the front or on the surface, dark brown to black color, among others.

The pH is another one of the best indicators to define the fermentative quality of silage. Tables 5 and 6 show the values of this variable in the silages of root and foliage from *M. esculenta*, of the variety INIVIT Y-93-4 and Señorita, respectively.

For INIVIT Y-93-4, the values were found between 3,7 and 4,5. Throughout the fermentation process, they were higher for the treatments with 100 % *M. esculenta* foliage, with highly significant differences at the evaluation moments (15, 30 and 60 days) with regards to T1 and T2. Meanwhile, at 45 days, the differences were significant among all the treatments ($p < 0{,}001$).

For the variety Señorita, the values varied between 3,8 and 5,0. The highest pH values were recorded in T3, except on day 30 of evaluation of the fermentation dynamics. In this variety, pH decreased with the increase of fermentation days, for which the lowest values were found since 45 days, for all the treatments. The combinations T1 and T2 showed significant differences with regards to T3, during the evaluation moments (15 and 45 days). At 60 days, all the treatments showed highly significant statistical differences among them ($p < 0{,}001$).

In general, in all the treatments of both varieties, pH remained stable during the 60 days fermentation lasted, although T3 (100 % *M. esculenta* foliage) reached the highest values (over 4,0). The *M. esculenta* root shows higher dry matter (DM) content than the foliage of this plant and besides, higher quantity of highly fermentable carbohydrates, which guarantees, with higher efficiency, the activity of lactic acid producing bacteria (LAPB) and of microorganisms in charge of decreasing the pH in lactic fermentations (Moura *et al.,* 2017). Hence silages with higher proportion of *M. esculenta* root showed lower values of this indicator: 3,7-3,9 for INIVIT Y-93-4 and 3,8-4,6 for Señorita, respectively.

Sánchez-Ledezma (2018) reported that pH depends on the DM content of the silage and on the proportion there is between proteins and soluble carbohydrates, considering that when silage reaches lower values than 4,2 it has achieved its fermentative stability. If fermentation is successfully developed and LAPB activity proliferates and they become the prevailing activity due to the production of lactic acid and other organic acids, pH decreases between 3,8 and 5,0 with regards to the species and forage characteristics (Garcés-Molina *et al*., 2004).

Hiriart (2008) states that the fall of this indicator should be as fast as possible, until reaching lower values than 4,2. This criterion coincides with that of Sánchez-Ledezma (2018), although it is preferred to be lower than 4,0 to produce stable silage in short time. Nevertheless, studies reported by Ososanya and Olorunnisomo (2015) confirm that a pH of 4,5 also allows to obtain a good-quality product.

Figure 1 shows the existing relation between pH and *M. esculenta* forage percentage in the variety INIVIT Y-93-4 in correspondence with the sampling moments. Increasing trend of pH is observed as the forage percentage increases, with the highest values in T3 (100 % forage). The model that explained with higher goodness of fit this relation was the second-order polynomic equation, with $R^2$ and adjusted $R^2$ in all cases, higher than 0,90.

In the case of the variety Señorita, there was no significant relation between the foliage percentage

Table 6. pH value of silages of forage and root from *M. esculenta*, variety Señorita.

| Treatment | Moments, days | | | |
|---|---|---|---|---|
| | 15 | 30 | 45 | 60 |
| | Mean ± SE | Mean ± SE | Mean ± SE | Mean± SE |
| T1-0 % foliage: 100 % root | $4{,}6^b \pm 0{,}020$ | $4{,}4 \pm 0{,}265$ | $3{,}9^b \pm 0{,}027$ | $3{,}9^b \pm 0{,}012$ |
| T2-25 % foliage: 75 % root | $4{,}6^b \pm 0{,}013$ | $4{,}4 \pm 0{,}280$ | $3{,}8^b \pm 0{,}095$ | $3{,}8^c \pm 0{,}019$ |
| T3-100 % foliage: 0 % root | $5{,}0^a \pm 0{,}075$ | $4{,}8 \pm 0{,}244$ | $4{,}6^a \pm 0{,}038$ | $4{,}6^a \pm 0{,}015$ |
| P - value | 0,001 | 0,502 | 0,000 | 0,000 |

a, b and c: different letters in the same column differ at $p < 0{,}05$

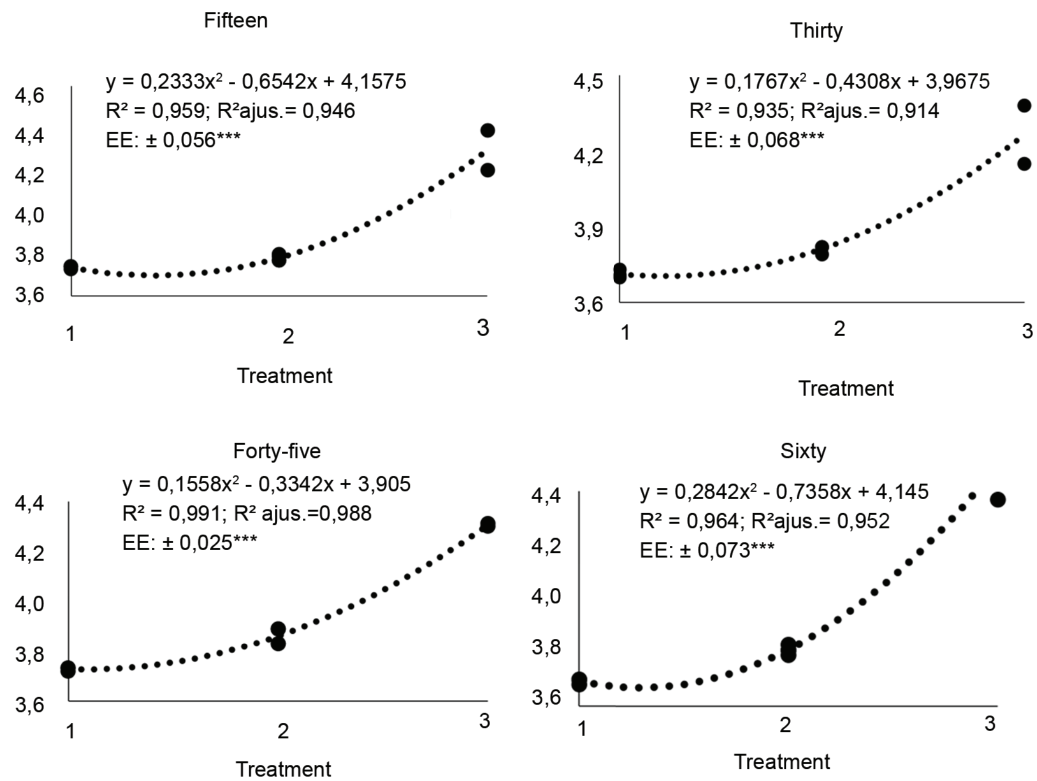


Figure 1. Regression of pH in the silage and percentage of forage from *M. esculenta*, variety INIVIT Y-93-4, in correspondence with the sampling moments.

T1-0 % foliage: 100 % root, T2-25 % foliage: 75 % root and T3-100 % foliage: 0 % root

in the treatments and pH. This can be an example that the silage was not stabilized at 60 days, moment in which the last sampling was carried out. In turn, the values found were higher than in the variety INIVIT Y-93-4.

According to Kung *et al.* (2018), the presence of N-$NH_3$ in the silages is conditioned by the content of free amino acids, the nitrates present in the forage and protein degradation, due to bacterial metabolism during fermentation. Its concentration offers an idea of the proportion of the proteins that have been unfolded during the ensiling, when it is expressed as percentage of total nitrogen. This quantity of unfolded proteins can be high or low, according to the quality of the fermentation process in the silo. Table 7 shows the N-$NH_3$ concentration of the silages studied in the variety INIVIT Y-93-4.

The content of ammoniacal nitrogen increased from 15 to 60 days of fermentation in all the treatments, mainly caused by the $NH_3$ generated by the above-mentioned proteolysis processes, which could have been present since the first phases of the silage production. Nevertheless, this increase did not influence the quality of the silage, because in

Table 7. N-NH3 concentration of silages of forage and root from M. esculenta, variety INIVIT Y-93-4 (mg N-NH3/100 mL).

| Treatment | Moments, days | | | |
|---|---|---|---|---|
| | 15 | 30 | 45 | 60 |
| | Mean ± SE | Mean ± SE | Mean ± SE | Mean± SE |
| T1-0 % Foliage: 100 % Root | 0,12$^{c}$ ± 0,0170 | 0,12$^{c}$ ± 0,0099 | 0,17$^{c}$ ± 0,0230 | 0,27$^{c}$ ± 0,0252 |
| T2-25 % Foliage: 75 % Root | 0,39$^{b}$ ± 0,0191 | 0,34$^{b}$ ± 0,0163 | 0,48$^{b}$ ± 0,0201 | 0,52$^{b}$ ± 0,0429 |
| T3-100 % Foliage: 0% Root | 0,66$^{a}$ ± 0,0264 | 0,82$^{a}$ ± 0,0992 | 0,98$^{a}$ ± 0,0662 | 1,42$^{a}$ ± 0,1697 |
| P - value | 0,000 | 0,000 | 0,000 | 0,000 |

a, b and c: different letters in the same column differ at $p < 0,05$

these silages there was stability of pH throughout the fermentative process, with final values between 3,7 and 4,5 (table 5). According to Kleinschmit and Kung (2006), $N\text{-}NH_3$ can be affected by pH in the silage. If pH is acid, the $N\text{-}NH_3$/NT content is lower. Meanwhile, if it is less acid, the $N\text{-}NH_3$/NT values are higher.

Significant differences ($p \leq 0,001$) were found in the $N\text{-}NH_3$ concentration among the different treatments. The highest values were found in T3, at all moments of evaluation, with regards to T1 and T2, which also differed between them. This is corroborated in figure 2, where the existing relation between N-NH3 and the inclusion percentage of *M. esculenta* foliage in the silage, is shown.

From the figure it is inferred that, for the different fermentation moments, there was a growing trend of nitrogen as the forage percentage in the silage increased, with the highest values in the treatment with 100 % forage (T3). The model that explained with higher goodness of fit this relation was the second-order polynomic equation, with $R^2$ and adjusted $R^2$, higher than 0,70.

Table 8 shows the $N\text{-}NH_3$ concentration of the silages from the variety Señorita. Increase of the ammoniacal nitrogen content was shown from 15 to 60 days of fermentation in all the treatments of this variety. In turn, significant differences ($p \leq 0,001$) were found among the treatments, with the highest values in T3, at 15, 30, 45 and 60 days, with regards to T1 and T2, which also differed between them.

Figure 3 shows the relation between $N\text{-}NH_3$ and the inclusion percentage of *M. esculenta* forage in the silage. For the different fermentation moments the same trend was proven as in the variety INIVIT Y-93-4; that is, growing increase of nitrogen as the forage percentage increased, with the highest values in the treatments with 100 % of forage (T3). The model that explained this relation with higher goodness of fit was the second-order polynomic equation, with $R^2$ and adjusted $R^2$, higher than 0,90, for which it is highly significant.

The $N\text{-}NH_3$ values for good-quality silage vary according to the forage type. In this study, in all the evaluated treatments, $N\text{-}NH_3$ was lower than the values described by Ojeda *et al.* (1991), Betancourt *et al.* (2005) and Hiriart (2008). $N\text{-}NH_3$ showed, in general, slight trend towards increase as the proportion of *M. esculenta* forage in the silages increased. Nevertheless, the quality of the treatments of *M. esculenta* forage and root was excellent; while the quality of *M. esculenta* root (100 %) was good. This was shown in the maintenance of the physical-chemical characteristics of silages, due to the significant contribution of the *M. esculenta* root to the fermentative process, regarding easily-fermentable carbohydrates and DM, which agrees with the report by López-Herrera *et al.* (2019).

## Conclusions

The fermentation dynamics of the silages with different proportions of forage and root from *M. esculenta*, variety INIVIT Y-93-4 showed adequate parameters of temperature, pH and $N\text{-}NH_3$ during the different moments of evaluation. The silages of both varieties showed good organoleptic characteristics.

The plant *M. esculenta*, due to its ensilable characteristics can constitute a valuable feeding resource for the elaboration of mixed silages, and is adequate for its utilization in animal production systems.

## Conflicts of interests

The authors declare that there is no conflict of interests among them.

## Authors' contribution

- Tania Sánchez-Santana. Generated the idea of the research, searched for bibliographic information and revised the manuscript.
- Fernando Ruz-Suárez. Executed the experiments with the corresponding measurements and searched for bibliographic information.
- Dariel Morales-Querol. Contributed to the execution of the experiments with the corresponding

Table 8. $N\text{-}NH_3$ concentration in silages of forage and root from *M. esculenta*, variety Señorita (mg $N\text{-}NH_3$/100 mL).

| Treatment | Moments, days | | | |
|---|---|---|---|---|
| | 15 | 30 | 45 | 60 |
| | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE |
| T1-0 % foliage: 100 % root | $0,04^{c} \pm 0,009$ | $0,03^{c} \pm 0,007$ | $0,09^{c} \pm 0,010$ | $0,18^{c} \pm 0,022$ |
| T2-25 % foliage: 75 % root | $0,42^{b} \pm 0,035$ | $0,95^{b} \pm 0,026$ | $1,02^{b} \pm 0,021$ | $1,17^{b} \pm 0,026$ |
| T3-100 % foliage: 0 % root | $1,32^{a} \pm 0,025$ | $1,40^{a} \pm 0,020$ | $1,53^{a} \pm 0,012$ | $1,90^{a} \pm 0,052$ |
| P - value | 0,000 | 0,000 | 0,000 | 0,000 |

a, b and c: different letters in the same column differ at $p < 0,05$

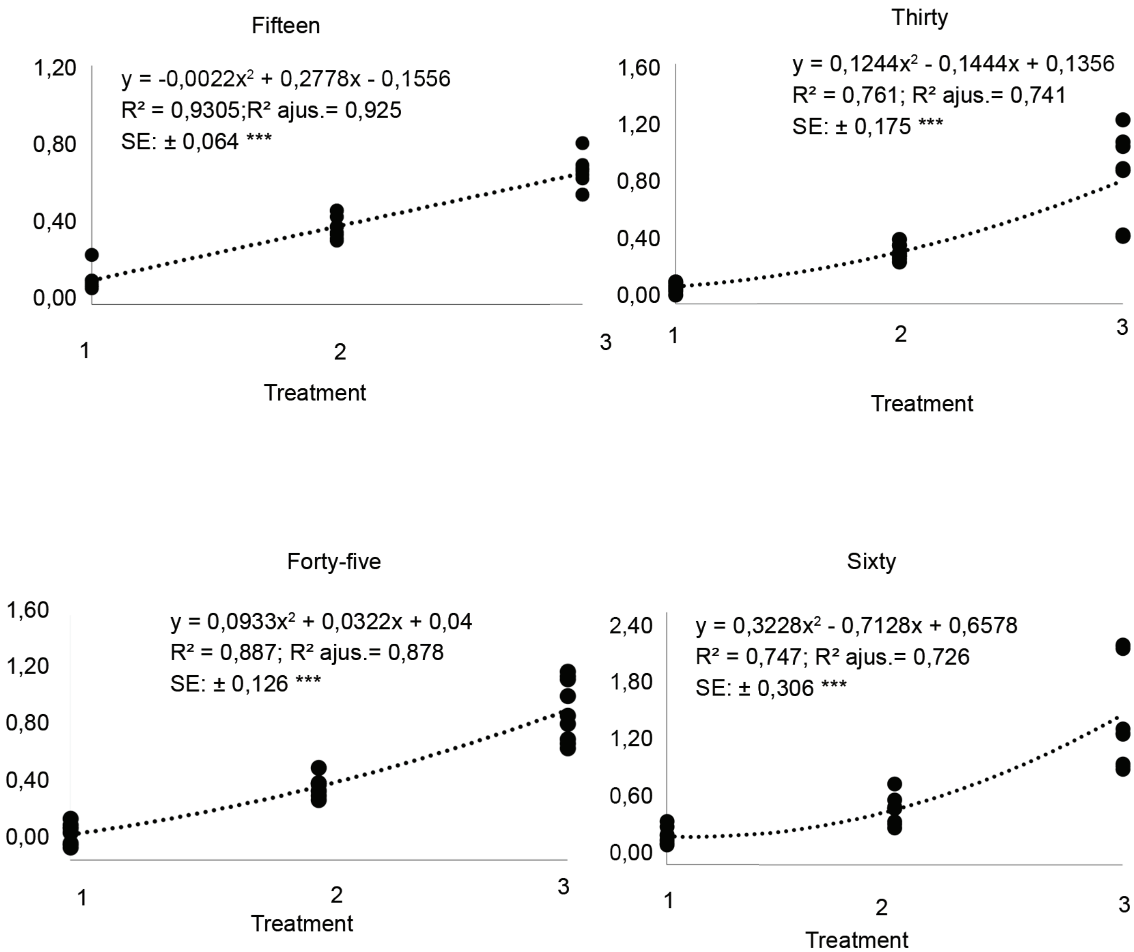


Figure 2. Regression of N-NH3 in the silage and percentage of forage from M. esculenta, variety INIVIT Y-93-4, in correspondence with the sampling moments.

T1-0 % foliage: 100 % root, T2-25 % foliage: 75 % root and T3-100 % foliage: 0 % root

measurements and searched for bibliographic information.

- Yuseika Olivera-Castro. Generated the idea of the research, searched for bibliographic information and revised the manuscript.
- Maritza Rizo-Alvarez. Contributed to the execution of the experiments with the corresponding measurements and searched for bibliographic information.
- Miguel Benítez-Alvarez. Contributed to the execution of the experiments with the corresponding measurements and searched for bibliographic information.

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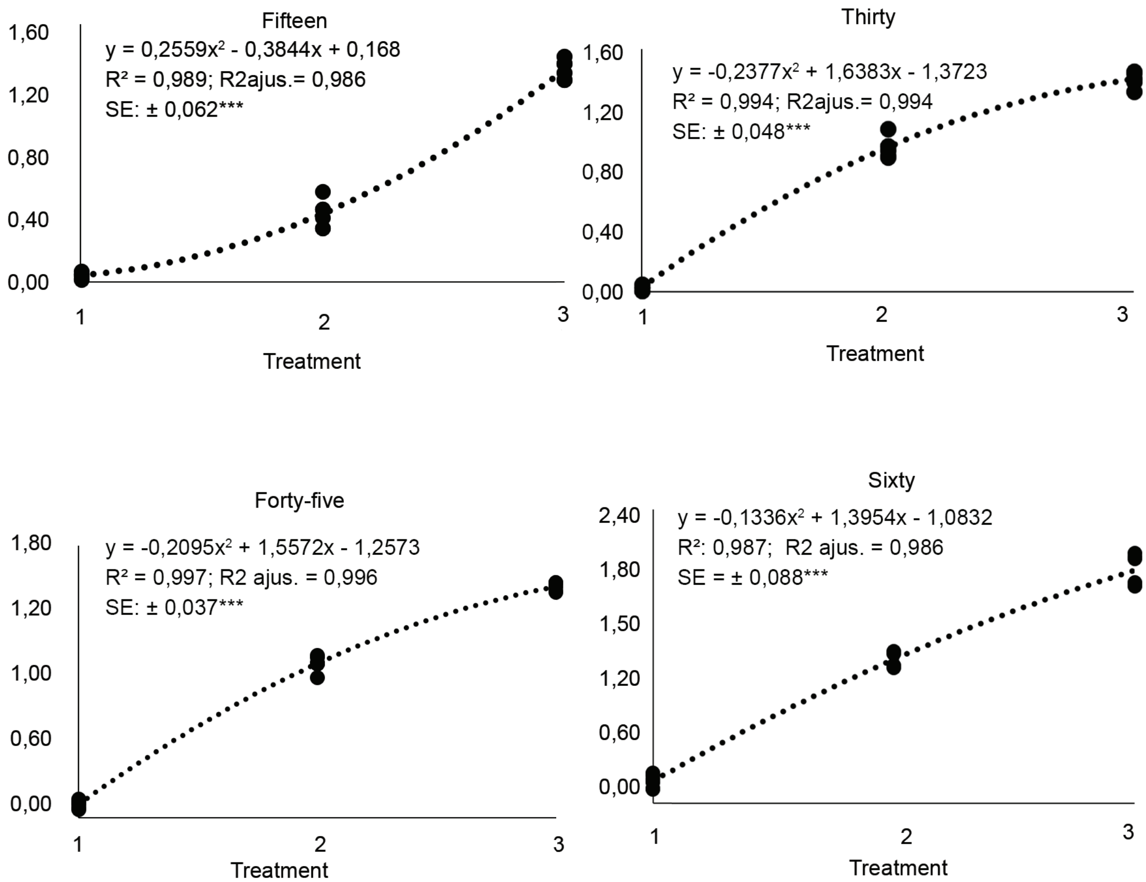


Figure 3. Regression of N-NH3 in the silage and percentage of forage from *M. esculenta*, variety Señorita, in correspondence with the sampling moments

T1-0 % foliage: 100 % root, T2-25 % foliage: 75 % root and T3-100 % foliage: 0 % root

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