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EVALUATION OF A SILAGE PRODUCED BY MIXTURE OF RESIDUES OF CASSAVA (MANIHOT ESCULENTA), POTATO (SOLANUM TUBEROSUM), EGGPLANT (SOLANUM MELONGENA) AND WATERMELON (CITRULLUS LANATUS), GENERATED IN SUPERMARKETS

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Abstract

This paper evaluates the physical, chemical and microbiological composition of silage obtained from mixtures of plant residues. The research was experimental with a quantitative approach, the data obtained from the response variables were analyzed using statistical tools for the subsequent interpretation of the data. For the execution of the experiment, plant residues of potatoes, cassava, eggplant and watermelon discarded in supermarkets in the city of Valledupar were used. For the production of silage, a completely random experimental design was applied with four treatments and three repetitions. The best treatment was selected through the analysis of variance (ANOVA) and comparison of means through the Tukey test. Three of the four alternatives for the production of silage are viable since they carry the process in a correct way because the pH values given suggest that there is an optimal production of lactic acid bacteria. The tests carried out comply with adequate characteristics in treatments two, three and four. Treatments containing the highest percentage of cassava showed the best values in fiber, carbohydrates and protein. While the silages that contained in greater proportion the potato were the richest in moisture.

Keywords: Silage, Vegetable Waste, Animal Feed, Supermarkets, Fermentation.

1. INTRODUCTION

According to the Food and Agriculture Organization of the United Nations – FAO, reducing food waste and losses became a global purpose, the figures are alarming, it is estimated that every year around 30% of cereals are lost and wasted; 40-50% of tubers, fruits and vegetables; 20% of oilseeds, meat and dairy products and 35% of fish. The causes of food waste in middle-and upper-income countries are mainly related to consumer behavior and existing policies and regulations to address other sector priorities.

In line with the United Nations "Globally, around 14 percent of food produced is lost between harvest and retail, while an estimated 17 percent of total global food production is wasted 11 percent in households, 5 percent in the food service and 2 percent in retail.

Reducing food losses and waste became a global purpose, this is because the figures are alarming, the causes of food waste in middle and high income countries are mainly related to consumer behavior and existing policies and regulations to address other priorities of the sector [1] [2].

Supermarkets demand high aesthetic standards for fresh products that lead to food waste, because they have strict quality characteristics on the weight, size and appearance of fruits and tubers, so the waste generated most of the time becomes part of animal feed. According to the National Planning Department in Colombia, 34% of the food in the country is wasted. The guilds that produce food for human consumption can be key to changing bad practices and finding a more efficient way to manage our food [3].

Depending on the processing activity where the weight reduction of the raw material used in food production is carried out, food losses or waste can be generated. It is a loss when it occurs during the activities carried out from agricultural production and industrial processing or transformation.

While food waste is generated during the distribution; retail trade, retail or retail trade and in activities aimed at the consumption of food. The causes by which food is lost or wasted can be very varied and multiple factors are involved such as climatic conditions, degree of industrial processing technologies, culture, habits or forms of consumption and logistical aspects, among others [4].

On the other hand, in the processing of raw materials to obtain silages, a series of fermentative processes are carried out, such as acetic, where plant cells allow the growth of Coliform bacteria that produce acetic acid from lactic acid at optimal temperatures between 18 to 25 ºC. likewise, lactic acid bacteria use sugars and other soluble carbohydrates that are part of forage raw materials in order to generate lactic acid under anaerobic conditions. Not having adequate conditions for the above, secondary fermentations may occur which are undesirable and should be avoided.

One of the most common is the so-called butyric fermentation, it is produced at temperatures between 20 to 40 ºC by bacteria that increase the ammonia concentration that favors the development of bacteria of the genus Bacillus that increase the ammonia concentration much more and generate conditions for the growth of contaminating microorganisms that can decompose the silage. Alcoholic fermentation, by yeast is recommended in small concentrations, excess alcohol in silage is a danger to livestock [5] [6] [7].

According to preliminary consultations in some supermarkets in the city of Valledupar, Cesar, Colombia, approximately 822 tons are currently generated annually, this is significant for a city that has around 545,000 inhabitants, so it is necessary to implement processes that use this waste in order to reduce negative impacts on the environment and the reuse of waste or food waste for animal feed through silage that can contribute to lowering investment costs in different businesses related to cattle.

In this work, we evaluated the composition, physico-chemical and microbiological of a silage obtained from mixtures of vegetable waste, vegetable residues, showed that we can use this type of waste in the production of silage, fulfilling all the requirements needed to carry out the process, and to be used as a supplement in animal feed, in addition to be useful for decreasing the losses and environmental pollution caused regularly by mishandling that is given to the organic waste.

Silage is a process that provides producers with a sustainable way of animal feeding over time, since vegetables are not degraded quickly, allowing them to be preserved for later use, offering to maintain the amount of nutrients that the food has, thus obtaining an animal feed that can be used at any time of the year.

2. MATERIALS AND METHODS

The research was experimental with a quantitative approach, the data obtained from the response variables were analyzed using statistical tools for the subsequent interpretation of the data. The experiment was conducted according to what was proposed by several authors [6] [7] [8] [9].

The samples were taken at random, in four supermarkets in the city of Valledupar, an experimental design was applied completely at random with four treatments and three repetitions. In search of the best treatment, it was evaluated through the analysis of variance (ANOVA).

for the comparison of the averages, the Tukey test was performed, it seeks to compare the individual means generated in an analysis of variance of several samples from different treatments. it allows to distinguish whether the results obtained are significantly different or not. The results of the analyses were calculated with a significance level of 5% probability of error, and the difference between groups was considered significant as long as $p < 0.05$. Twenty-three kilograms of potato (S. tuberosum), twenty-four kilograms of cassava (M. esculenta), three kilograms of watermelon (C. lanatus), and three kilograms of eggplant (S. melongena) were collected for each treatment.

Table 1. Organization of experimental design

Treatments	Concentration in percentages (%) of raw materials in mixture			
	Potato	Cassava	Eggplant	Watermelon
T1	70	25	3	2
T2	55	40	3	2
T3	25	70	3	2
T4	30	65	3	2

To all mixtures were added 0.4% molasses.

The residues were collected in the morning hours, they were taken to the laboratories (CIDI) of the Popular University of Cesar, for subsequent washing and fractionation with a steel knife to a particle size of 1.5 cm, size that the authors decided, following bibliographic recommendations, on food for ruminants, in which the particle size must be small enough so as not to hinder the correct compaction of the silage and that it must have a particle size large enough to provide the animal with effective fiber.

For each treatment, 10 grams of sample was taken from the waste mixture and the physicochemical analyzes of humidity, pH, acidity, ash and microbiological analyzes of molds, yeast, aerobic mesophiles, total and fecal coliforms and E. coli were performed.

Subsequently, the twelve bag silos were prepared, since each of the four treatments had three repetitions, each silo with a weight of three kilograms, weight determined by the authors, these were filled taking into account what was established in the experimental design, to measure the pH, observe the process and its stabilization, were made apart from the aforementioned silos, twelve one kilogram silos, equivalent to each treatment with three repetitions, one of each repetition was opened at five days, another at ten and the other at fifteen days, this in order not to open the silo of the twenty days, and cause some alteration in the process.

The silage was opened after twenty days of the fermentative process, and the humidity, pH, acidity, protein, fat, carbohydrates, fiber, ash, calcium, sodium and microbiological of molds, yeasts, aerobic mesophiles, total coliforms, fecal and E. coli were determined. Each sample is performed with three repetitions.

The pH was performed by the method 10.041/84 of the Association of Official Analytical Chemists - A.O.A.C using a pH meter brand OHAUS model STARTER 3100. 100 g of sample were used, which were added in a commercial blender, being liquefied in 200 milliliters of distilled water.

Then, it was filtered and the resulting liquid was proceeded to measure the pH. The titratable acidity was determined by titration with a solution of NaOH 0.1 N, it took 10 g of the mixture of raw materials used, were introduced in a blender, in 20 milliliters of distilled water, filtered and the solution obtained, we added three drops of phenolphthalein and then it is stirred manually and is valued solution of NaOH 0.1 N, by means of a burette, graduated, until the solution obtained previously took a pale pink colour that persisted for 30 seconds.

The humidity was carried out by the gravimetric method 930.150 /90 of the A.O.A.C, using a drying oven, desiccator with silica gel, digital scale with an accuracy of ± 0.001 g porcelain crucible. The sample weight was 10 g. For this test the sample was fractionated into much smaller sizes than the one provided for silage in order to ensure the process.

It was subjected to oven drying for 24 continuous hours, the ash determination was carried out by method 942.85/90 of the A.O.A.C. The sample already dry obtained from the test of moisture in the crucible porcelain calcined at 550 °C in a muffle, the fat was determined by method 920.39/90 of the A.O.A.C using a computer Soxhlet in addition to this a refrigerant, beaker of 1000 ml, cork rubber, clamps, bracket, universal, a thimble, hoses, ball volumetric, balance of high precision.

The fiber determination was carried out by the A.O.A.C. method 962.09/90. The fat-free sample is acid digested in the presence of 0.225 N H_2SO_4 and alkaline digested in the presence of 0.313 N NaOH, using a heating plate.

The protein was determined by the volumetric Kjeldahl method, which determines the concentration of nitrogen present in the sample to then be transformed, through a factor, into protein, which in the case of fruits is 6.25.

The carbohydrate content is calculated by subtracting from 100 the sum of the content of dietary fiber, proteins, fats and ash moisture [10] [11] [12].

3. RESULTS AND DISCUSSION

3.1 Physicochemical and Microbiological characteristics of the initial mixture of raw materials.

FIGURE 1: DISCARDED VEGETABLE WASTE IN SUPERMARKET

The physicochemical characteristics of the initial mixture for the treatments yielded the following results: The humidity values were in the range of 69.15 and 72.28% humidity with a standard deviation of 1.2116. Treatment two was the one with the highest moisture concentration (72.28%). The pH values ranged from 5.87- 6.19 at the beginning of the silage process.

With a standard deviation of 0.12. Likewise, the acidity values ranged from 0.99% to 1.05% as lactic acid with a standard deviation of 0.044 and the ash were between 1.08% to 1.2% with a standard deviation of 0.05. On the other hand, the presence of microorganisms is high, molds and yeasts are greater than 13 x 102 cfu/gr, mesophilic aerobes above 17 x 103 cfu/gr, Total coliforms and fecal Coliforms greater than 11000 cfu/gr and typical presence of Escherichia coli. Similar values were reported in other studies [7] [13] [14]. The above values are taken as a starting point to compare the changes in the product by the silage process.

3.2 Physicochemical and Microbiological characteristics of the silage product

FIGURE 2: SILAGE OF VEGETABLE RESIDUES: CASSAVA, POTATO, EGGPLANT AND WATERMELON

Moisture content for silage

The moisture values in the silage ranged from 66.63 to 73.5%, with T1 being the treatment with the highest humidity and T3 the lowest. There were no significant differences between the treatments (1-2) and (3-4). There were differences between the rest of the treatments. These differences are marked by the percentage of cassava and potato used in each of the treatments. These values were close to that of 72.24% of other researchers [15] [16]. Although the results obtained in this research are slightly higher than those considered acceptable values between 60 to 65% [17]. This level of humidity is due to characteristics of the raw materials, the watermelon present in all treatments, increases humidity since it has 91% in its nutritional composition, which could limit the intake of dry matter in some animals. The humidity values in T1 and T2 could be due to the fact that the composition of these treatments has the potato in a greater proportion and it could have 80%, unlike cassava which has a humidity percentage of 60 to 65%. The differences in humidity between the beginning of the process and the end are very low, treatments one and two show a slight increase in humidity due to the runoff of potato juices, since it is the raw material of greater quantity in the mixture of these treatments, treatments three and four are in an optimal humidity range.

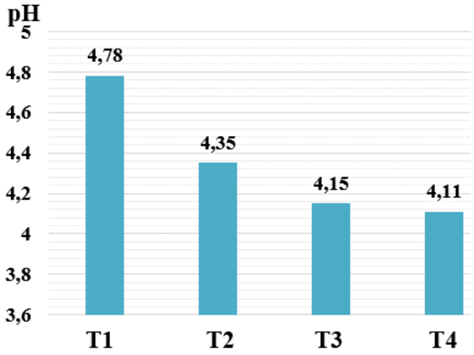
Ash content for silage

Product data silage are among 1,07%, 1.16%, there was no significant difference between the treatments, the results are in line with the nutritional composition of the raw materials that are in greater percentage in each of the treatments, as the pope reaches values raw 1.20% [18], while the cassava values of 1.3% [19]. The data from the beginning of the process with those obtained at the end did not suffer significant variations, since there are no losses of dry matter within the process, there should also be no variation in the concentration of the ashes [20]. These values were lower than those obtained in other studies of a forage sorghum silage that reached 4.2%.

pH values for each silage treatment

A reduction in the pH values was observed compared to those at the beginning, which suggests that the fermentation process was carried out with total normality. The obtained pH values in the silages varied from 4.11 to 4.78, there were no significant differences between treatment 3-4, but among the rest of them, these Data are similar to those obtained by multiple works cited above.

FIGURE 3: pH VALUES FOR EACH SILAGE TREATMENT

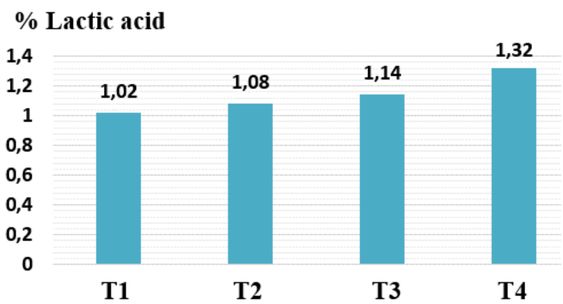


The results obtained in the silage guarantee the quality in treatments three and four. Treatments one and two handle very high pH that together with the high humidity can favor the growth of undesirable bacteria of the genus Clostridium. At pH equal to or less than 5,0 lactic acid bacteria are the organisms predominant, converting the sugar into lactic acid which inhibits microbial growth by increasing the amount of acid lactate, the pH of the silage lower in to a level that inhibits the presence of microorganisms that induce rot.

Titratable acidity values for each silage treatment

The acidity values ranged from 1.02% to 1.32%, There were significant differences between the pairs related to treatment four, because this is the one with the greatest variation in acidity, there are no significant differences between the other treatments, the increase in acidity was evidenced compared to the beginning of the process. Acidity is one of the most important factors for the preservation of silage, the higher the acidity the lower the microbial activity inside the silage mass. likewise, the formation of lactic acid allows to improve the microbiological stability since it restricts the growth of other bacteria that cause decomposition.

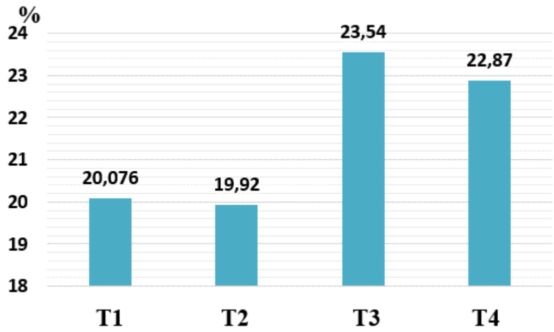
FIGURE 4: TITRATABLE ACIDITY VALUES FOR EACH SILAGE TREATMENT



Carbohydrate content for each silage treatment

The data obtained ranged from 19.92 to 23.54%, with T3 and T4 being the treatments with the highest values. This is due to the initial characteristics of the raw materials, which have high values of carbs in your nutritional composition, the pope is between 18.7 % to 19.31% carbohydrates, and cassava has about 35%, the contribution of carbohydrates is used as substrates by microorganisms during fermentation for the production of lactic acid, a minimum of 6 to 12% of the soluble carbohydrates are required for the own silage fermentation [21].

FIGURE 5: CARBOHYDRATE CONTENT FOR EACH SILAGE TREATMENT



There are no significant differences between the treatments. Treatments 1 and 2 have a higher concentration of potato, while treatments 3 and 4 have a higher cassava content, these differences are marked from the initial bromatological composition of the residues. The results are similar to those obtained by Cerda and Manterola in 2018 in their bean silage, which was 22.8%, this is due to the fact that the raw materials used in this research have a high carbohydrate content. it is important to remember that groups of microorganisms degrade sugars and other soluble carbohydrates present in forages to produce lactic acid. the degradation of the plant cells of the silage material generates that the concentration of carbohydrates, fats and proteins can diffuse out of the mass becoming nutrients for the large number of microorganisms present.

Protein content for silage

The protein content in the final silage is in a range of 0.71 to 1.3%, there are no significant differences between the treatments (2-4) and (3-4). There are differences between the rest of the treatments. What values reflect loss of protein during the process because during the fermentation is no degradation of the proteins in the fodder and thus have low quality, so there should be no variation in the concentration of protein of a good silage, however, the possibility exists that part of the protein true become another type of nitrogen compounds such as ammonium product of the first phase of fermentation in the silage [22].

Fiber content for silage

The values of fiber ranged between 4,44 and 7,31%, there were no significant differences between the treatment (1-2), while there were no significant differences between the other treatments, being better to the treatment three, this is due to the fact that in this treatment the concentration of cassava is higher than in the other, because cassava has a percentage of fibre 1.44% [19], higher than that of the pope, which would explain the differences between the treatments, it can also be attributed to that the goods are not removed the shell which increased the values of fiber in the silage. The values obtained for fiber are higher than those reported by other studies with values between 1.74 and 2.88% [23] and from 2.84 to 6.23% [24] in Colombia and Cuba respectively.

Microbiological analysis for silage

The microbiological results show the considerable decrease of the microbial load in the evaluated parameters of molds and yeasts are less than 3 x 103 cfu/gr, mesophilic aerobes below 1 x 102 cfu/gr and negative for total Coliforms, fecal coliforms and Escherichia coli. The above verifies that the fermentation process to obtain the silage was carried out properly and is a safe method in the reduction or elimination of undesirable microorganisms [25] [26].

Recommended Waste Composition for Silage Intended for Animal Feed

According to the results found at the end of the silage process, after the study of the statistical analysis and the technical regulations issued according to the Colombian Agricultural Institute - ICA in 1999, three of the treatments (Treatments two, three and four) have characteristics of a good silage, treatment number three is chosen as recommended composition: potato 25%, cassava 70%, eggplant 3%, watermelon 2% and 0.4% molasses. This treatment, with the pH level characteristic of a good silage (4.15), as demonstrated by the production of lactic-acid bacteria, which prevent the development of other fermentations and ensure the conservation, their levels of carbohydrates (23.54%), proteins (1.30%), and fiber (7.31%), demonstrate statistical superiority in the analysis of multiple ranges of each of the parameters of analysis.

Likewise, it is necessary for its implantation to be done in accordance to the principles of discussion, collaborative participation, respect and critical thinking by the various disciplines of the institution. For its application, an initial diagnostic phase is proposed, then a design and planning phase, an execution phase and, finally, an evaluation and feedback phase.

4. CONCLUSION

Three of the four alternatives for the elaboration of a silage are viable, the process takes place under normal conditions reported by other antecedents. The pH values during fermentation show that lactic fermentation is carried out under optimal conditions for the growth of lactic acid bacteria.

Treatments two, three and four are the best results. In the moisture factor, adequate stabilization was not achieved in the silos, which may be due to the characteristics of the raw materials used.

The production of lactic acid achieved in all treatments an excellent inhibition of undesirable microorganisms, which is favorable for the final characteristics of the silage and its conservation over time, the treatments that contained a higher percentage of cassava showed better values in fibers, carbohydrates and protein.

While the silages that contained the highest concentration of potato were those that presented the highest concentration of moisture in the end.

The fiber values are high due to the inclusion of the shells of the raw materials used. Likewise, the percentage of carbohydrates was high, due to the characteristics of the raw materials used, especially cassava. Microbiological analyses showed a large reduction in the initial amount, as well as inhibition of coliforms and E. coli, found at the beginning of the process.

The recommended composition is treatment 3 since it presented the best results in the parameters analyzed in this research, however, only T1 can be ruled out due to its high moisture content and the pH values obtained, the other treatments also have significant nutritional characteristics and comply with a correct fermentation.

It was possible to evaluate the composition, physico-chemical and microbiological of a silage obtained from mixtures of residues of cassava (M. esculenta), potato (S. tuberosum), eggplant (S. melongena), and watermelon (C. lanatus), generated in supermarkets, these residues have nutritional characteristics that ensure the process of silage, due to its high content of carbohydrates, necessary for optimal fermentation, the addition of molasses was necessary to ensure the fermentation inside the silo and not run the risk of the development of other fermentations.

The above results demonstrate the opportunity to reduce the pollution caused in the environment by the waste for the manufacturing of a silage that contribute to the feeding of cattle and serve as a basis to develop in-depth other works in favor of the livestock sector of the Department of Cesar by having an accurate information of the composition, physico-chemical and microbiological of this potential food item which will allow to raise future research projects and advance knowledge in the field in order to produce silages specific trade for each animal species, providing producers with a feeding option.

According to the results shown, silage is the best option for the use of these types of waste since it allows its reuse as animal feed and provides producers with an opportunity to reduce the high cost of food supply in the animal production process. Likewise, this work serves as a basis to propose a strategy that can reduce the pollution caused in the environment by these food residues, not only in stores, markets or supermarkets, it can also be implemented in homes in order to collect and use on a large scale for animal feed, providing producers with a food supplement option.

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